MARYLAND DEPARTMENT OF NATURAL RESOURCES

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Maryland Tributary Strategy Upper Western Shore Basin Summary Report for 1985-2003 Data DRAFT

January 2005

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Maryland Tributary Strategy Upper Western Shore Basin Summary Report for 1985-2003 Data DRAFT – January 2005

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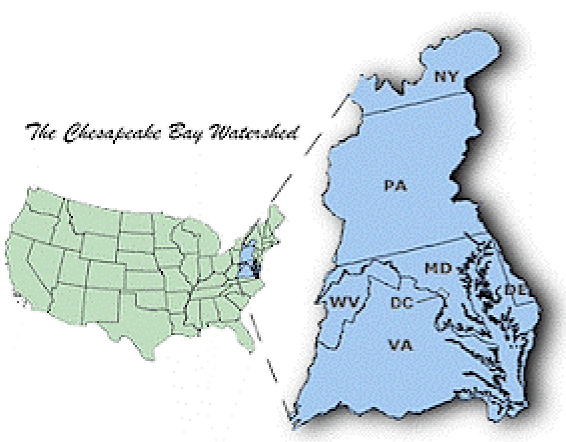
Introduction

The Chesapeake Bay is the largest estuary in North America. A national treasure, the Bay is famous for providing delicious seafood as well as a myriad of recreational and livelihood opportunities, such as boating, fishing, crabbing, swimming, and bird-watching.

By the 1970s, however, our treasured Bay was in serious decline. In 1975, the United States Congress directed the Environmental Protection Agency (USEPA) to conduct a comprehensive study of the most important problems affecting the Chesapeake Bay. The findings of this study formed the crux of the first Chesapeake Bay Agreement, signed in 1983 by Maryland, Virginia, Pennsylvania, Washington DC, the Chesapeake Bay Commission and the USEPA. Additional scientific information gained from monitoring data and modeling efforts was used to amend that Agreement, resulting in the 2000 Chesapeake Bay Agreement (http://www.chesapeakebay.net/agreement.htm).

Science showed that three of the biggest problems facing the health of the Chesapeake Bay and its tributaries (the rivers and streams that flow into the Bay) are excess nitrogen, phosphorus, and sediments. The nutrients nitrogen and phosphorus fuel excessive algae growth. These algae, as well as suspended sediments, cloud the water and prevent Bay grasses from getting enough light; Bay grasses provide essential habitat for crabs and fish as well as food for waterfowl. When algae blooms die, they decompose using up essential oxygen. This lack of oxygen kills bottom-dwellers such as clams and sometimes fish.

Figure UWS1



Another problem with excess nutrients is that they sometimes favor the growth of harmful algae. Harmful algae can be toxic to aquatic animals and even humans. For more details on the Bay's ecosystem and the problems facing it, see http://www.dnr.state.md.us/Bay/monitoring/mon_mngmt_actions/monitoring_mgmt_actions.html.

The health and vitality of the Chesapeake Bay is a product of what happens in the watershed, the land area the drains into it. The Chesapeake Bay watershed is enormous at 64,000 square miles, and includes land in six states plus Washington DC (Figure UWS1).

To help achieve Maryland's share of the reductions in nitrogen, phosphorus, and sediment to the Bay and its tributaries, a Tributary Strategy Team has been appointed for each of the ten Chesapeake Bay subwatersheds in Maryland:

- Upper Western Shore Basin
- Patapsco/Back Rivers Basin
- Lower Western Shore Basin
- Patuxent River Basin
- Upper Potomac River Basin
- Middle Potomac River Basin
- Lower Potomac River Basin
- Upper Eastern Shore Basin
- Choptank Basin
- Lower Eastern Shore Basin

Each team is comprised of business leaders, farmers, citizens, and state and local government representatives who work together to find the best ways to reduce nutrient and sediment inputs to the Bay.

This report provides:

- Upper Western Shore basin characteristics
- Nutrient and sediment loadings based on model results (the model is developed using monitoring data)
- Overview of monitoring results
    - links to indepth non-tidal water quality information
    - tidal and non-tidal water quality status and trends (based on monitoring data, i.e., measured concentrations from 1985 to 2003)
    - Bay grasses acreage over time
    - long-term information on benthic (bottom-dwelling) community health
    - information on phytoplankton
    - information on zooplankton
    - nutrient limitation information
- individual wastewater treatment plant outputs

The goal of this report is to show current status of the habitat and water quality (how good or bad it is) and long-term trends (how has water quality and habitat improved or worsened since 1985) provided within the context of information about the basin.

Maryland Upper Western Shore Basin Characteristics

The basin drains an area of 685 square miles, including all of Harford County and portions of Carroll, Baltimore, and Cecil Counties (Figure UWS2). Larger water bodies include the Susquehanna River, Bush River, Gunpowder River, Little Gunpowder Falls, Deer and Octoraro Creeks, Conowingo Pool, Loch Raven and Pretty-boy Reservoirs and tidal embayments in the lower portions of the basin, including Middle River. Most of this basin lies in the Piedmont physiographic province, but some of it lies in the Coastal Plain province.

Census population from 2000 for the basin is 487,000. Major population centers in the Upper Western Shore include Bel Air, Carney, Middle River, Edgewood, and Perry Hall.

The Maryland Department of Planning land use categories are defined as follows (Figure UWS3):

- urban – includes residential, industrial, institutional (such as schools and churches), mining, and open urban lands (such as golf courses and cemeteries)
- agriculture – includes field, forage, and row and garden croplands; pasturelands; orchards and vineyards; feeding operations; and agricultural building/breeding and training facilities, storage facilities, and built-up farmstead areas
- forest – includes deciduous forest, evergreen forest, mixed forest, and brush
- water – includes rivers, waterways, reservoirs, ponds, and the Bay
- wetlands – includes marshes, swamps, bogs, tidal flats, and wet areas
- barren – includes beaches, bare exposed rock and bare ground

Agricultural land and forest/wetlands are the dominant land uses in the basin (38 percent each). Urban land comprises 25 percent of the Upper Western Shore.

About 38 percent of the Upper Western Shore is in agricultural land. A series of best management practices have been planned to help reduce non-point source loads. BMP implementation for animal waste management, nutrient management plans, conservation tillage and cover crops, forest conservation and buffers, shore erosion control, marine pumpouts, and stormwater management retrofits and conversion are making good progress toward Tributary Strategy Goals. For other issues, such as treatment and retirement of highly erodible land, runoff control, stream protection, erosion and sediment control, septic connections and pumping, and urban nutrient management, progress toward Tributary Strategy Goals has been slower.

Urban land comprises a quarter of the Upper Western Shore. Of this developed land, 85 percent is classified as low intensity development. Five percent is high intensity, and 11 percent is commercial development.

Nearly 80 percent of the housing in the basin is in urban areas, with most of the remainder in rural areas. Slightly lower percentages of housing rely on municipal water and sewer systems, with 70 percent of the basin's housing using a public water source and 75 percent relying on a public sewer. Despite these statistics, point sources are not among the most significant pollutant sources in the basin. There are five major wastewater treatment facilities in the Upper Western Shore basin, and biological nutrient removal has been implemented at four of them. Appendix A contains graphs of average monthly nutrient loads from the basin's major wastewater treatment facilities.

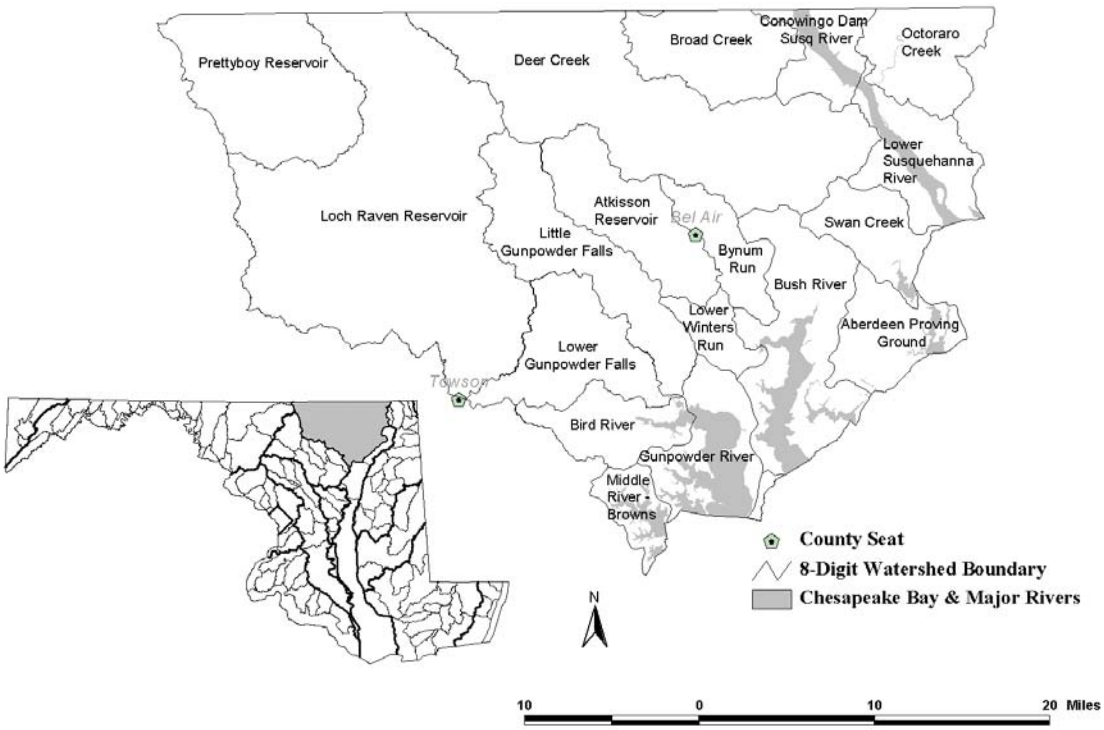
The Chesapeake Bay Program model categorizes nutrient and sediment loads from both point sources (end of pipe inputs from wastewater treatment plants and industrial outfalls) and non-point sources. The non-point loads are estimated from a variety of sources including land cover, agriculture records, etc. Generally, the categories in Figures UWS5-UWS7 include:

- point sources – out of pipe from waste water treatment plants and industrial releases
- non-point sources
    - urban – from industrial, residential, institutional, mining and open urban lands
    - agriculture –from row crop, hay, pasture, manure acres
    - forest –from forested lands
    - mixed open –from non-agricultural grasslands including right-of-ways and some golf courses
    - atmospheric deposition to water – deposited from the atmosphere directly to water

For more detailed information, see the document *Chesapeake Bay Watershed Model Land Use Model Linkages to the Airshed and Watershed Models* at http://www.chesapeakebay.net/pubs/1127.pdf.

As of 2002, the most significant contributor of nitrogen, phosphorus, and sediment to Maryland's Upper Western Shore was agricultural sources (Figures UWS5-UWS7). These account for 39 percent of the basins' nitrogen load. Point sources contribute 21 percent and urban sources account for 18 percent of the basin's nitrogen load. For phosphorus, agriculture contributed about a third. Urban sources, mixed open lands, and point sources contributed 30, 18, and 16 percent, respectively. Agricultural land contributed 69 percent of sediment loads in the basin. Urban, forested, and mixed open lands each made much smaller contributions (14, 10, and 7 percent respectively). Figure UWS4 shows the location of wastewater treatment plants in the basin, and Appendix A show total nitrogen and total phosphorus loadings from these treatment plants.

Figure UWS2 – Map of Maryland's Upper Western Shore Basin



Prepared by: Maryland Department of Natural Resources - 2000

UPPER WESTERN SHORE
Restoration Action Strategy

Figure UWS3 – 2000 Land Use in the Upper Western Shore Basin

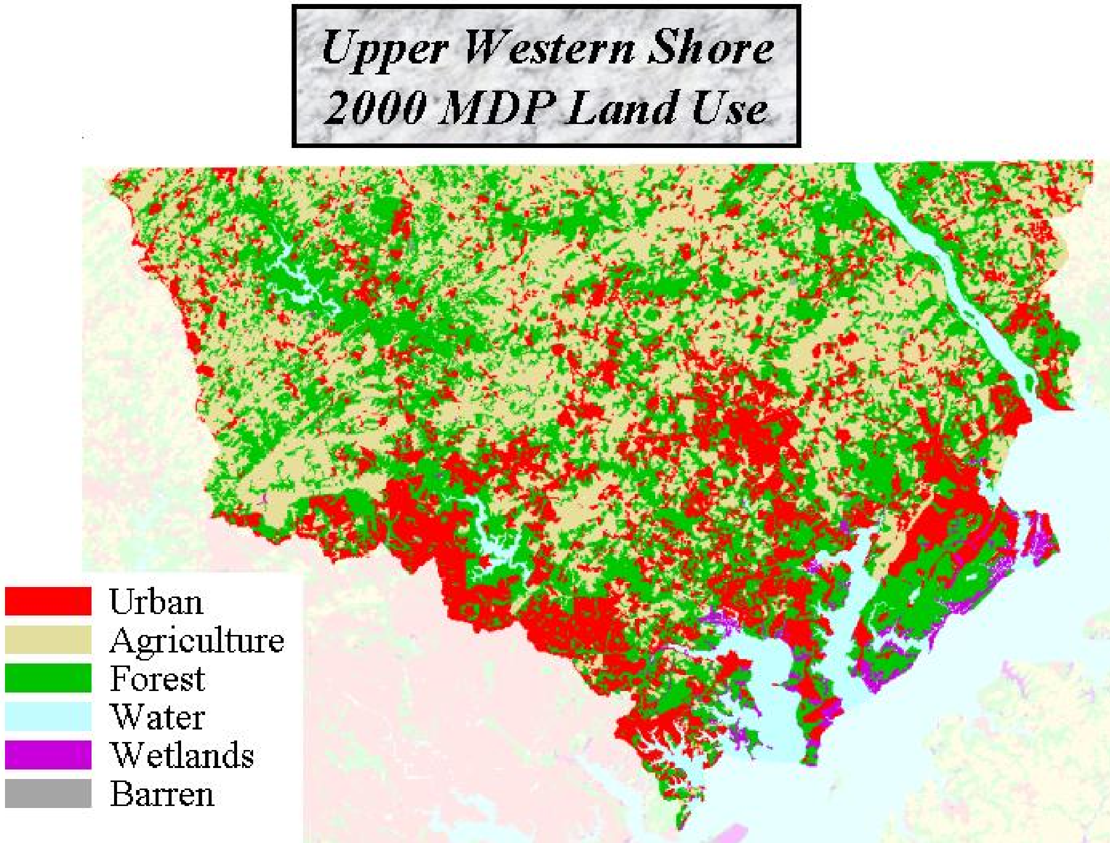


Figure UWS4– Wastewater Treatment Plants in the Upper Western Shore Basin

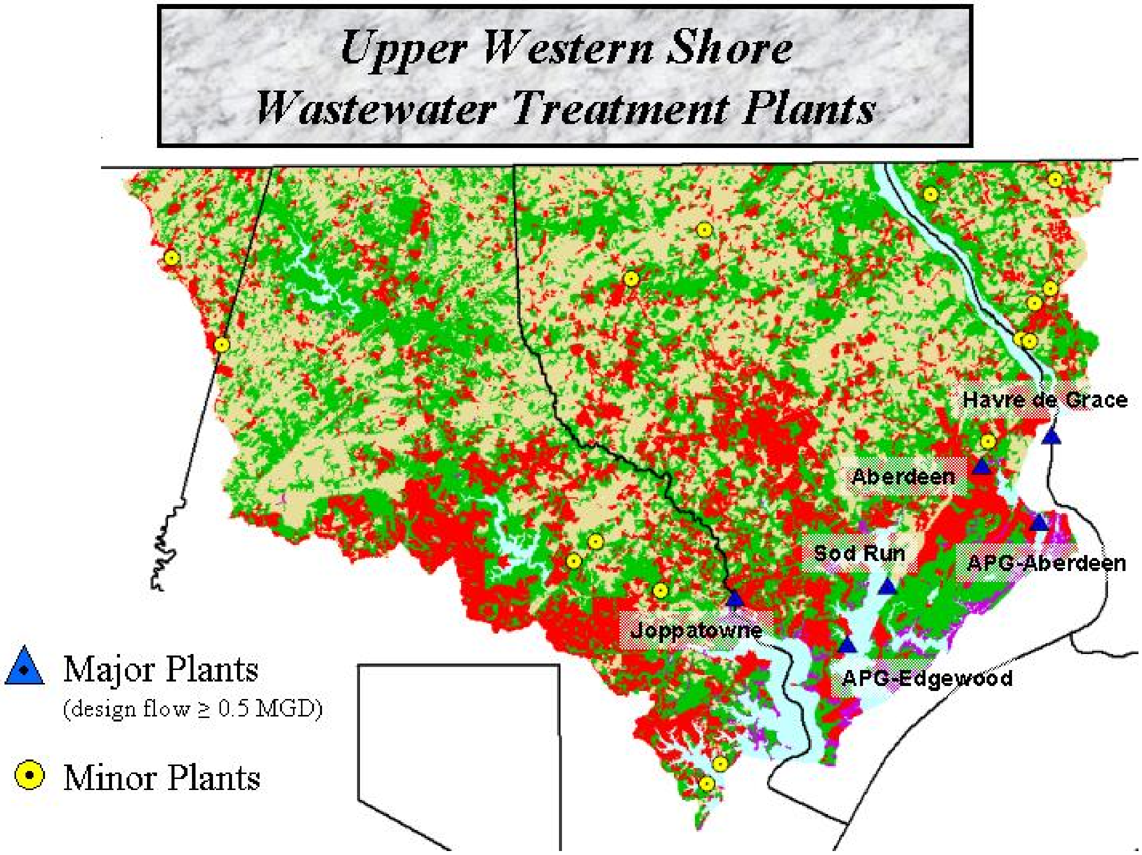


Figure UWS5 – 1985 and 2002 Nitrogen Contributions to the Upper Western Shore by Source.

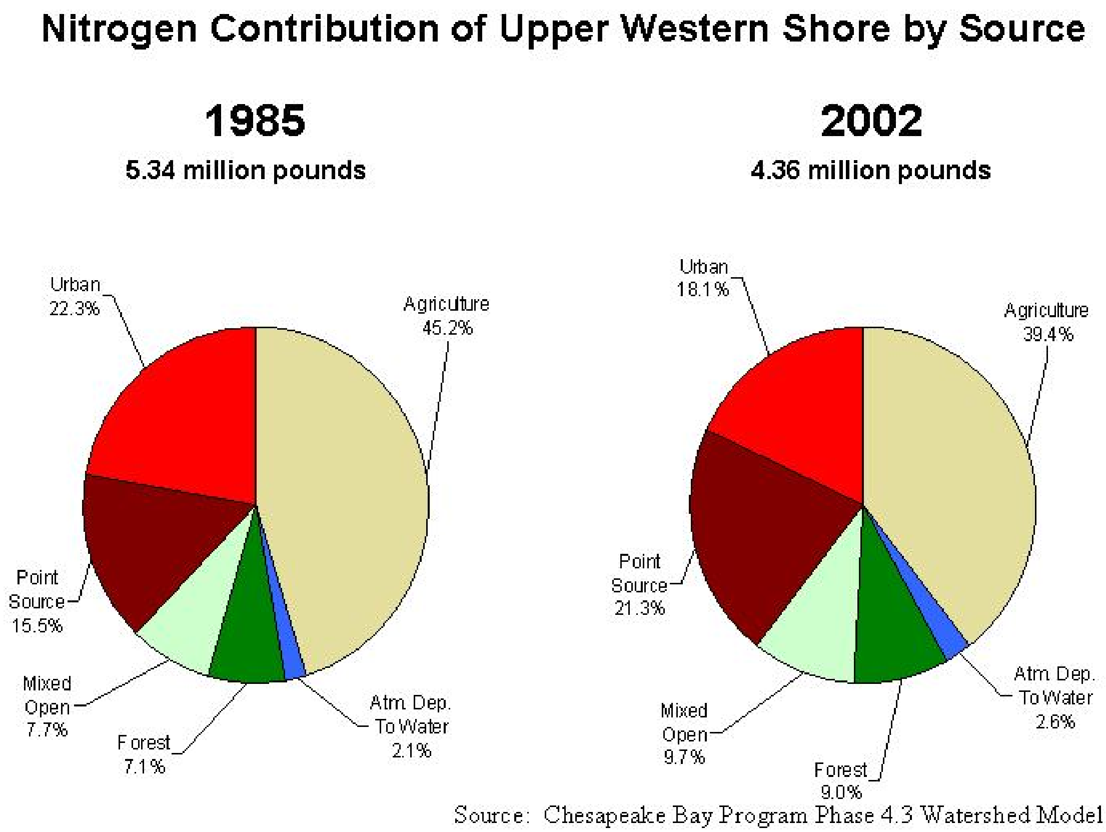


Figure UWS6 – 1985 and 2002 Phosphorus Contributions to the Upper Western Shore by Source.

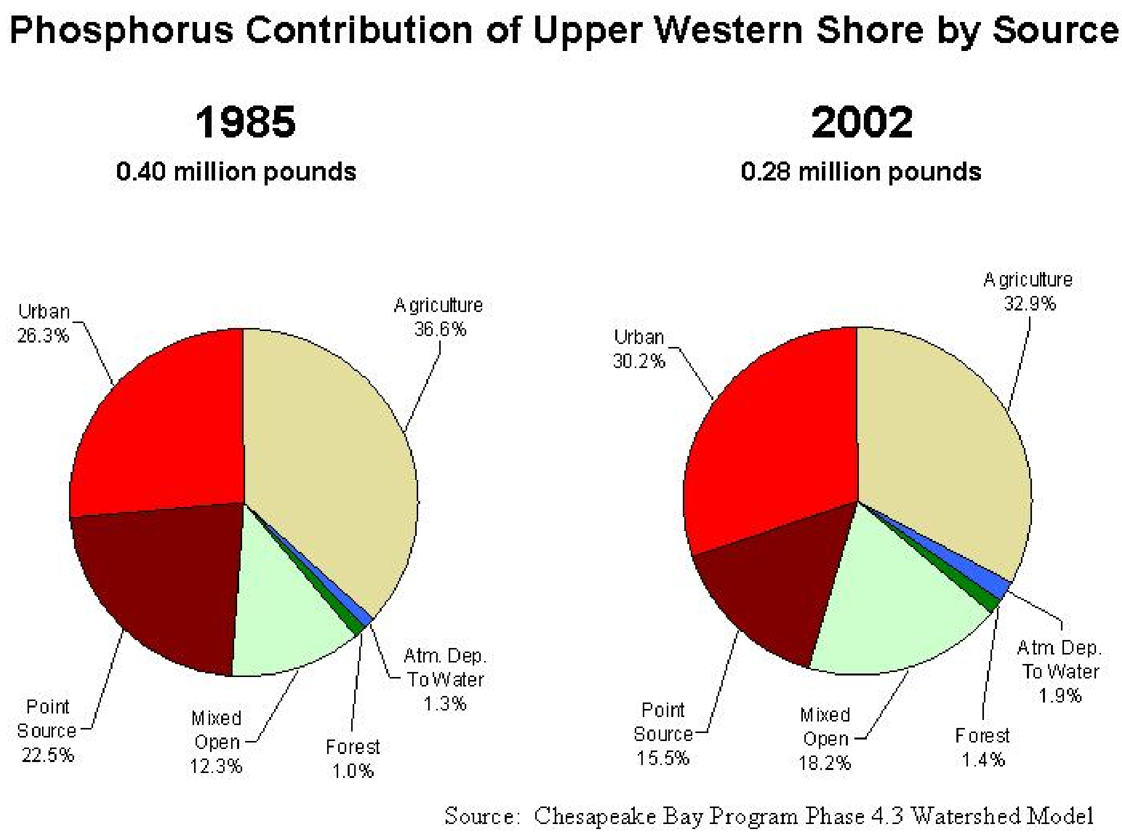
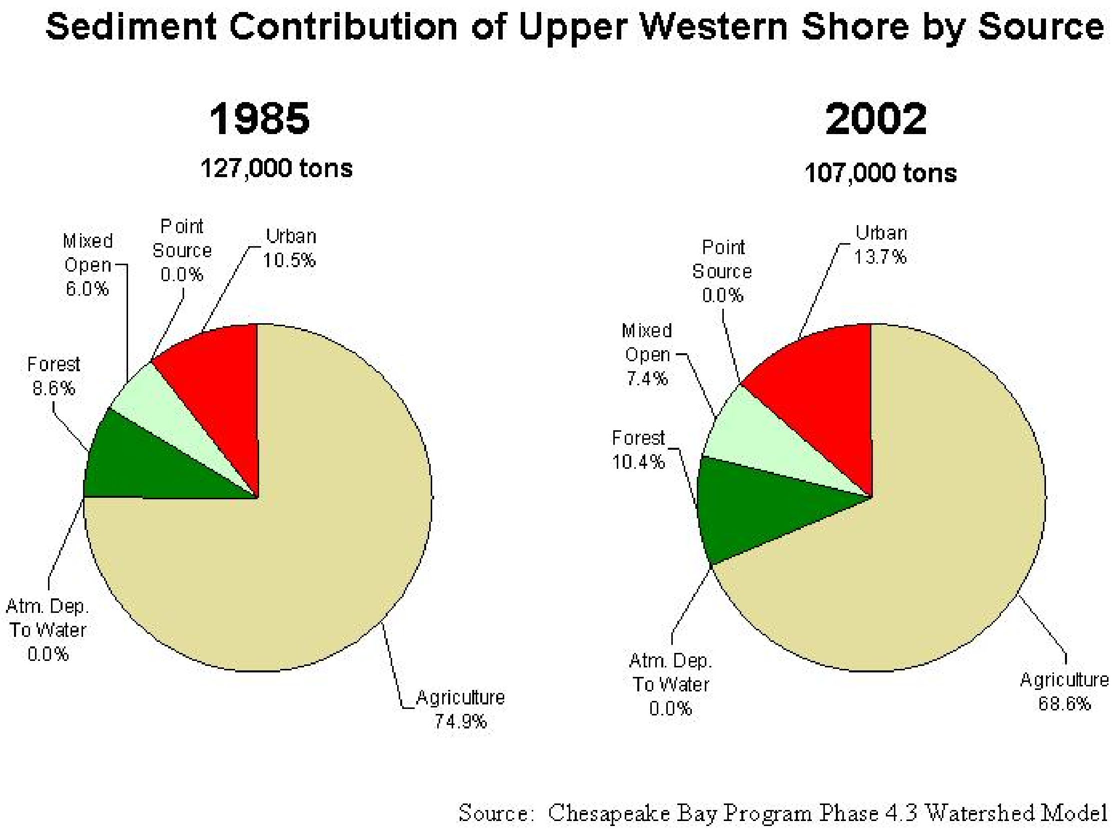


Figure UWS7 – 1985 and 2002 Sediment Contributions to the Upper Western Shore by Source.



Overview of Monitoring Results

The following sections present results from monitoring four aspects of the ecosystem: water and habitat quality, submerged aquatic vegetation (SAV, i.e., bay grasses), the benthic (bottom-dwelling) community, and nutrient limitation. Unless otherwise noted, the data are from the State of Maryland's long-term monitoring programs.

Water and Habitat Quality

Non-tidal Water Quality Monitoring Information Sources

Much useful information on non-tidal water quality is available on the Internet. The State of Maryland's Biological Stream Survey (MBSS) basin fact sheets and basin summaries are available at:
http://www.dnr.state.md.us/streams/mbss/mbss_fs_table.html
MBSS also reports stream quality information summarized by county at:
http://www.dnr.state.md.us/streams/mbss/county_pubs.html In addition to these reports and fact sheets, detailed and more recent information and data are also available on the MBSS website: **http://www.dnr.state.md.us/streams/mbss**

Water quality information collected by Maryland's volunteer Stream Waders is available at: **http://www.dnr.state.md.us/streams/mbss/mbss_volun.html**

Continuous Water Quality Monitoring Data

Continuous monitoring data have been collected since 2003 at six stations in the Upper Western Shore Basin:

- Otter Point Creek (Bush River)
- Lauderick Creek (Bush River)
- Mariner's Point Park (Gunpowder River)
- Aberdeen Proving Grounds (Gunpowder River)
- Strawberry Point (Middle River)
- Cutter Marine (Middle River)

Data on dissolved oxygen, water temperature, salinity, pH, turbidity, and fluorescence (which estimates algae levels) were collected every 15 minutes during the warmer months giving a picture of daily and tidal changes in water quality. View current data as well as archived data on our Eyes on the Bay website at www.eyesonthebay.net.

Water Quality Mapping

Spatially-intensive water quality mapping has been conducted in the Bush, Gunpowder, and Middle Rivers since 2003. Cruises were conducted once or twice a month during the warmer months. Data on dissolved oxygen, water temperature, salinity, pH, turbidity, and fluorescence (which estimates algae levels) were collected every 4 seconds as the boat moved through the water. The data points are interpolated and maps are created. The maps provide a snapshot in time of the surface variability of these important water quality parameters. View these maps on our Eyes on the Bay website at www.eyesonthebay.net.

Long-term Water Quality Monitoring

Good water quality is essential to support the animals and plants that live or feed in the Upper Western Shore tributaries. Important water quality parameters are measured at five long-term tidal monitoring stations in the Upper Western Shore, including nutrients, water clarity (Secchi depth), dissolved oxygen, total suspended solids, and algal abundance.

Current status is determined based on the most recent three-year period (2001-2003). For dissolved oxygen, the current concentrations are compared to ecologically meaningful thresholds to assign a status of good, fair, or poor. State thresholds have not been established for the other parameters, although a water quality criteria document has been completed by the Chesapeake Bay Program—http://www.chesapeakebay.net/baycriteria.htm—and new water quality criteria (for dissolved oxygen, water clarity, and chlorophyll) are currently being developed by the Maryland Department of the Environment—http://www.mde.state.md.us/ResearchCenter/Data/waterQualityStandards/index.asp. Until the new water quality critieria have been approved, the current data through 2003 are compared to a baseline data set, and assigned a status of good, fair, or poor, which is only a *relative* status compared to the baseline data. Trends are determined using a non-parametric test for trend (the Seasonal Kendall test). For a detailed description of the methods used to determine status and trends, see http://www.dnr.state.md.us/Bay/tribstrat/status_trends_methods.html.

Total nitrogen, total phosphorus, total suspended solids and dissolved oxygen levels are relatively good at the tidal monitoring stations (Bush River, Gunpowder River, and Middle River), and there are no significant long-term trends at those stations. Nonetheless, algal levels are poor and not improving at the Bush River station. Algal levels have improved at the Middle River and Gunpowder stations. Secchi depths are relatively fair to good at the tidal stations. See Figures UWS8 – UWS13.

Figure UWS8 – Total Nitrogen Status and Trends.

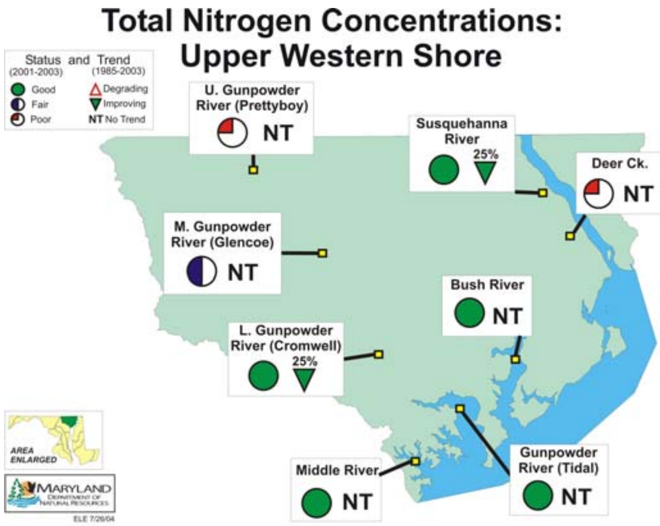


Figure UWS9 – Total Phosphorus Status and Trends.

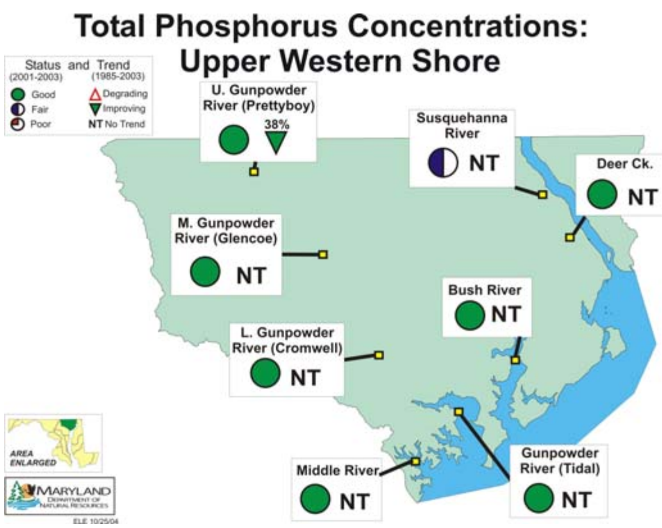


Figure UWS10 – Chlorophyll *a* Status and Trends

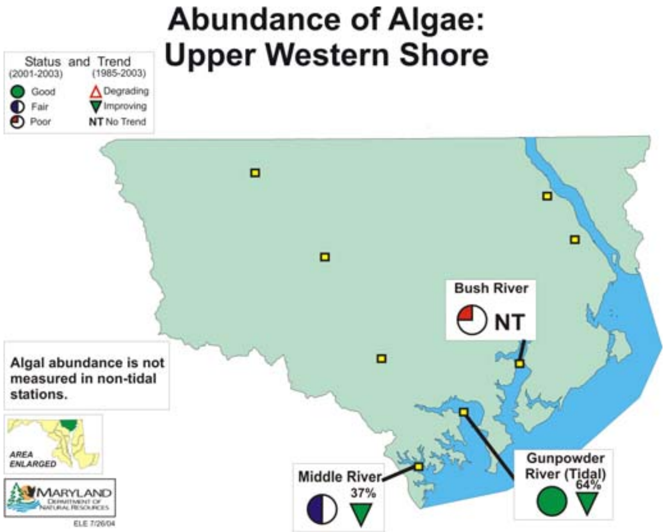


Figure UWS11 – Total Suspended Solids Status and Trends.

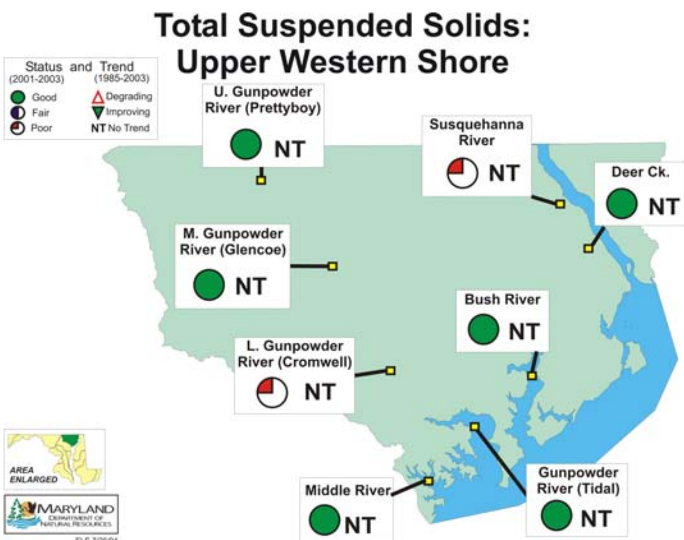


Figure UWS12 – Water Clarity (Secchi Depth) Status and Trend

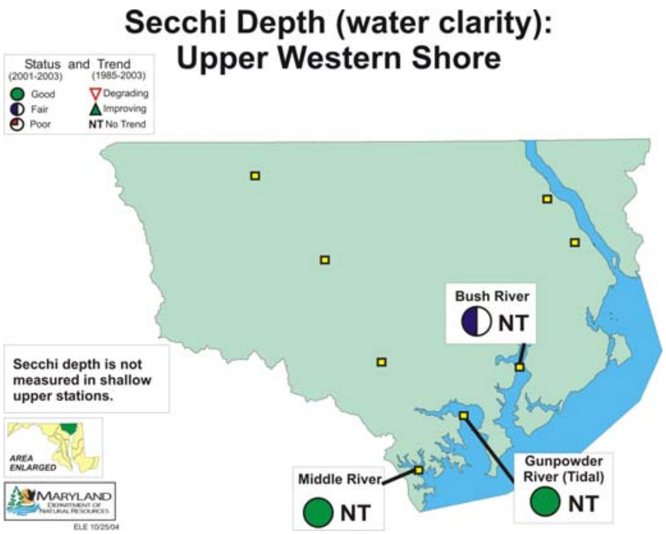
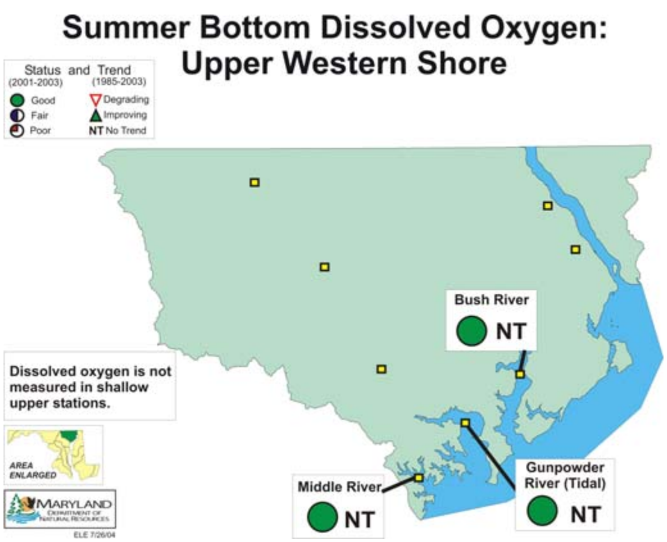


Figure UWS13 – Summer Dissolved Oxygen Status and Trends



Non-tidal stations show a couple of improving trends, and vary from relatively good to poor with respect to nitrogen, phosphorus and suspended solids. Note that the Glencoe station is between Pretty Boy and Loch Raven reservoirs; Cromwell station is just below the Loch Raven dam. Middle River has low freshwater flow resulting in a poorly flushed system.

Unspecified toxic pollutants caused waterbodies on and around Aberdeen Proving Grounds (Bush River) to be listed as impaired; elemental phosphorus from nonpoint sources caused Spesutie Narrows to be listed as well. Elevated copper and BHC levels have been found in some areas.

Bay Grasses (Submerged Aquatic Vegetation–SAV)

The well-defined linkage between water quality and submerged aquatic vegetation (SAV) distribution and abundance make SAV communities good barometers of the health of estuarine ecosystems. SAV is important not only as an indicator of water quality, but it is also a critical nursery habitat for many estuarine species. Blue crab post-larvae are 30 times more abundant in SAV beds than adjacent unvegetated areas. Similarly, several species of waterfowl are dependant on SAV as food when they over-winter in the Chesapeake region.

The Chesapeake Bay Program has developed new criteria for determining SAV habitat suitability of an area based on water quality. The APercent Light at Leaf@ habitat requirement assesses the amount of available light reaching the leaf surface of SAV after being attenuated in the water column and by epiphytic growth on the leaves themselves. The document describing this new model is found on the Chesapeake Bay Program website (www.chesapeakebay.net/pubs/sav/index.html). The older AHabitat Requirements@ of five water quality parameters are still used for diagnostic purposes.

The Bush River has had only periodic SAV occurrence (www.vims.edu/bio/sav/), though there was a phenomenal expansion of SAV in 2003, to 390 acres, or 250 percent percent of the revised goal (Figure UWS14**)**. Due to flight restrictions following the September 11, 2001 terrorist attacks, no data were collected for 2001. In 2000, the bulk of the SAV was located in Church Creek, Bush Creek, Otter Point Creek and Dove=s Cove. Ground-truthing throughout the river by the Aberdeen Proving Ground environmental staff and citizens has found 13 species, with the three most common being; milfoil, coontail and wild celery. From water quality-monitoring data obtained from the station located at the railroad bridge near Gum Point indicates that phosphorus levels meet the SAV habitat requirements; percent light at leaf and the concentrations of algae and suspended solids are borderline; and, light attenuation fails the SAV habitat requirements (Figure UWS15). Nitrogen is not applicable in this oligohaline environment.

The Gunpowder River had generally low abundance of SAV (www.vims.edu/bio/sav/) until 1996 (Figure UWS14). In 2000, the SAV coverage exceed the goal of 2,254 acres, reaching 2,424 acres. Due to flight restrictions following the September 11, 2001 terrorist attacks, no data were collected for 2001. SAV acreage declined to 463 acres in 2002 and 489 acres in 2003. Typically, most of the SAV is found throughout the Dundee/Saltpeter Creek complex and Day=s Cove areas with fringing beds in much of the Gunpowder. Ground-truthing throughout the river by the Aberdeen Proving Ground environmental staff and citizens found 14 species, with the three most common being; milfoil, wild celery and coontail. The Department of Natural Resources has been removing the invasive floating plant water chestnut from the Bird River. Water chestnut is an exotic species that can out-compete native submerged species. The spiked seeds of this plant can also pose a hazard to people swimming or water skiing in the area (http://www.dnr.state.md.us/bay/sav/water_chestnut.html). Water quality monitoring data obtained from the station located at the railroad bridge near Oliver Point indicate phosphorus meets the habitat requirements and percent light at leaf, light attenuation and the concentrations of algae and suspended solids are borderline(Figure UWS15). Nitrogen is not applicable in this oligohaline environment.

Middle River has had fairly variable SAV coverage over the last 15 years. Year 2000 had the highest coverage of SAV recorded by the aerial survey (740 acres or 88 percent of the goal (www.vims.edu/bio/sav/) (Figure UWS14). Due to flight restrictions following the September 11, 2001 terrorist attacks, no data were collected for 2001. Years 2002 and 2003 showed declines in coverage (629 and 391 acres respectively). Most of the SAV in 2000 was mapped at the mouth of the river, particularly Galloway Creek. Ground-truthing by the Army Corps of Engineers staff and citizens has found seven species of SAV in this area, listed here by frequency of occurrence: milfoil, horned pondweed, coontail, elodea, wild celery, redhead grass and curly pondweed. Data from the water quality monitoring station located near Wilson Point indicate that phosphorus, percent light at leaf, light attenuation and the concentrations of suspended solids and algae are borderline in respect to the habitat requirements (Figure UWS15). Nitrogen concentrations are not applicable to this oligohaline environment.

Figure UWS14 – Submerged Aquatic Vegetation in the Upper Western Shore Basin.

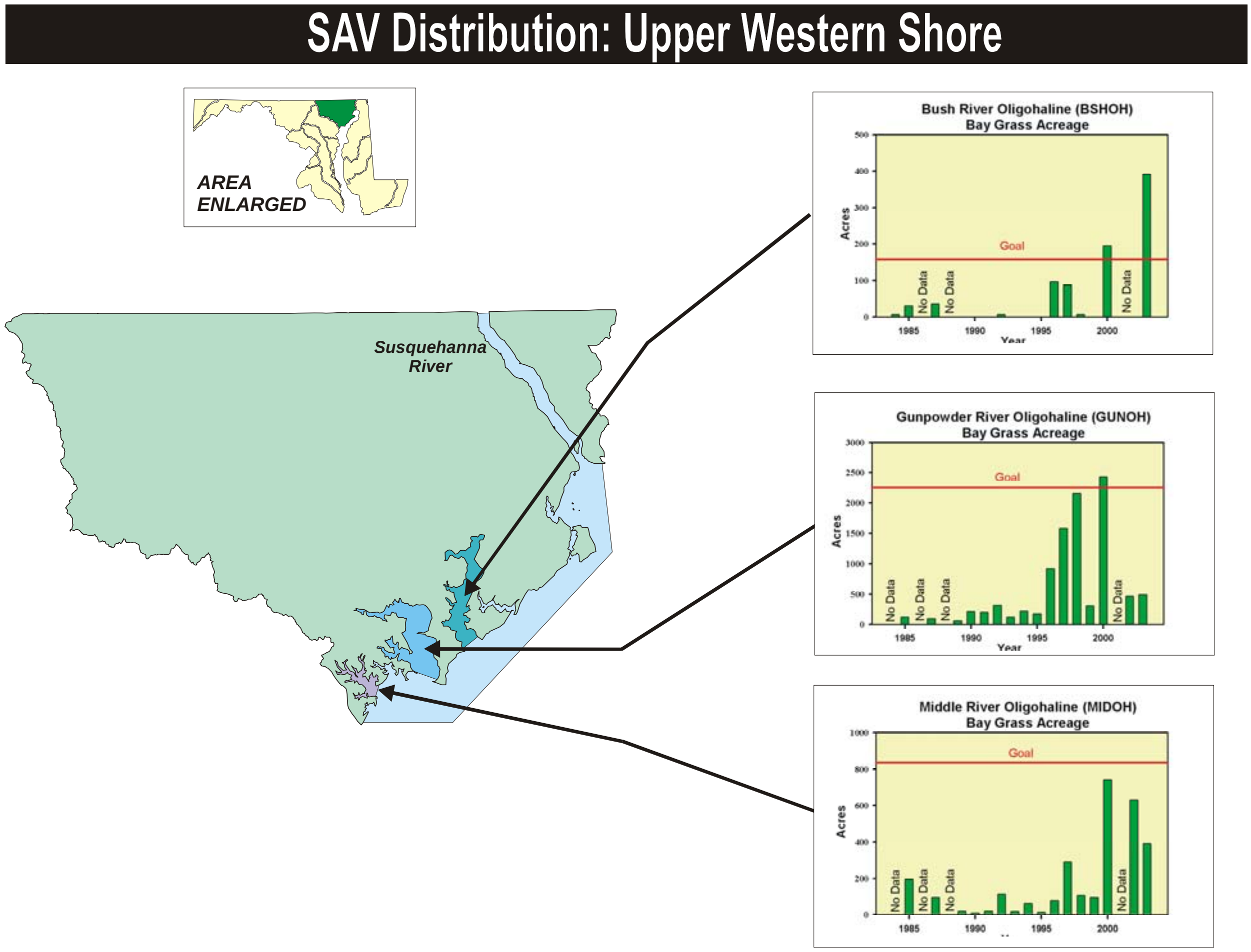


Figure UWS15 – Submerged Aquatic Vegetation Habitat Requirements in the Upper Western Shore Basin.

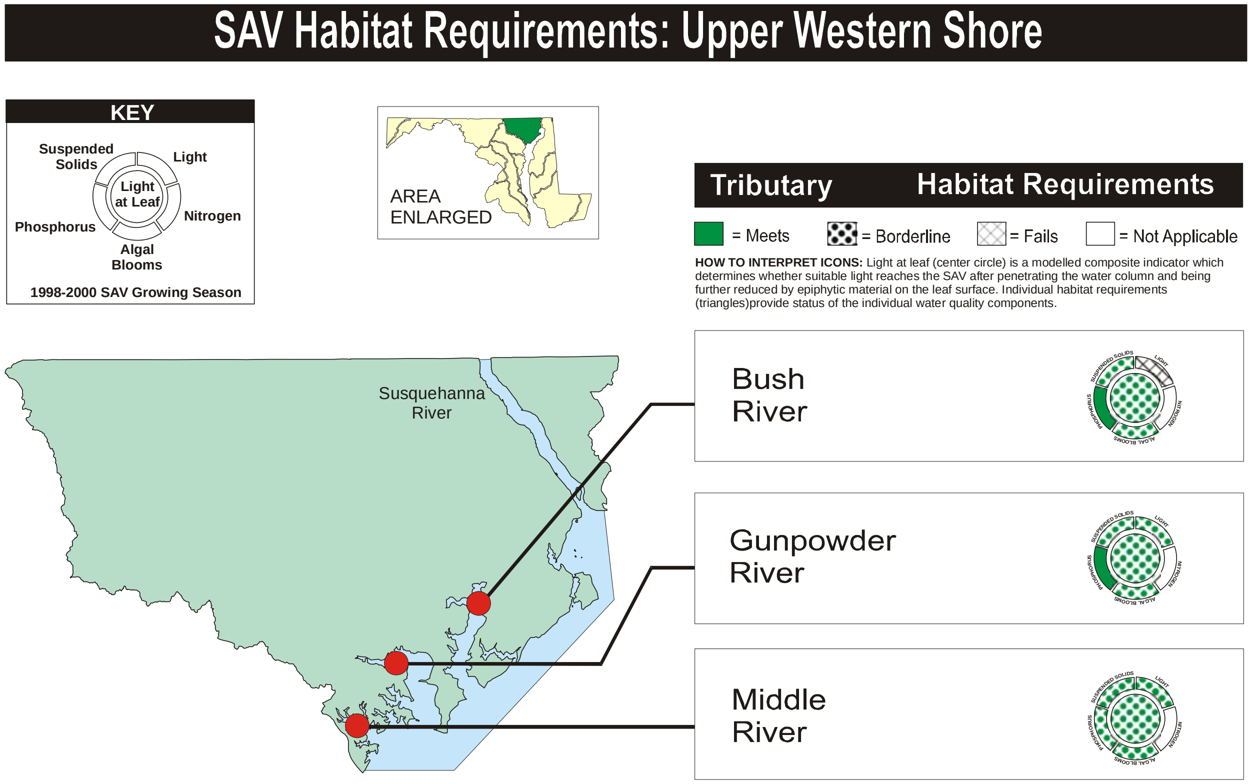


Figure 2: SAV habitat requirement attainment on the Upper Western Shore

Benthic Community

The benthic community forms an integral part of the ecosystem in estuarine systems. For example, small worms and crustaceans are key food items for crabs and demersal fish, such as spot and croaker. Suspension feeders that live in the sediments, such as clams, can be extremely important in removing excess algae from the water column. Benthic macroinvertebrates are reliable and sensitive indicators of estuarine habitat quality.

Benthic monitoring includes both probability-based sampling (sampling sites are selected at random) and fixed station sampling (the same site is sampled every year). A benthic index of biotic integrity (B-IBI) is determined for each site (based on abundance, species diversity, etc.). The B-IBI serves as a single-number indicator of benthic community health. For a more details on the methods used in the benthic monitoring program see http://esm.versar.com/Vcb/Benthos/backgrou.htm

Benthic communities in Upper Western Shore basin tributaries were only moderately degraded for the period 1999-2003. Probabilities of observing degraded benthos in these tributaries ranged from 38 to 41 percent (Figure UWS16). The Middle River had the least number of degraded sites among the three tributaries. Good benthic community condition in the Middle River is consistent with observations of good water quality status for this river. The Gunpowder showed patterns of degradation over a large area. In contrast, the Bush River showed degradation in the upper reaches of the estuary. Degraded sites in the Bush River were numerically dominated by pollution tolerant organisms, mostly tubificid oligochaetes. This is consistent with excess algal growth and reduced water clarity in this region of the river.

Figure UWS16. Total number of sites, degraded sites, and probabilities (90 percent confidence limits) of observing degraded benthos, non-degraded benthos, or benthos of indeterminate condition for Upper Western Shore Basin tributaries, 1999-2003.

Segment	**Tributary**	**Total No. Sites**	**No. Deg. Sites**	**P Deg.**	**P Non-deg.**	**P Indeter.**
MIDOH	Middle	4	1	37.5 (1.3–75.1)	37.5 (1.3–75.1)	50.0 (9.8–90.2)
GUNOH	Gunpowder	13	5	41.2 (21.5–60.9)	17.6 (2.4–32.9)	52.9 (33.0–72.9)
BSHOH	Bush	9	3	38.5 (16.2–60.7)	15.4 (0–31.9)	61.5 (39.3–83.8)

Nutrient Limitation

Like all plants, phytoplankton need nitrogen, phosphorus, light, and suitable water temperatures to grow. If light is adequate and the water temperature is appropriate, phytoplankton will continue to grow as long as unlimited amounts of nutrients are available. If nutrients are not unlimited, then the ratio of nitrogen to phosphorus affects phytoplankton growth. (Phytoplankton generally use nitrogen and phosphorus at a ratio of 16:1, that is, 16 times as much nitrogen is needed as phosphorus.) If one of the nutrients is not available in the adequate quantity, phytoplankton growth is 'limited' by that nutrient. If both nutrients are available in enough excess (regardless of the relative proportion of them) that the phytoplankton can not use them all even when they are growing as fast as they can under the existing temperature and light conditions, then the system is 'nutrient saturated.'

Nitrogen limitation occurs when there is insufficient nitrogen, i.e., there is excess phosphorus. Nitrogen limitation often happens in the summer and fall after stormwater flows are lower (so less nitrogen is being added to the water) and some of the nitrogen has already been used up by phytoplankton growth during the spring. If an area is nitrogen limited, then adding nitrogen will increase phytoplankton growth.

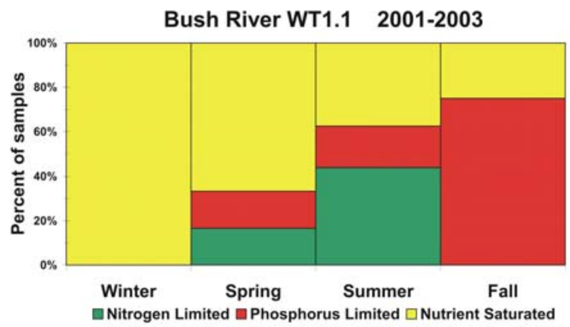
Phosphorus limitation occurs when there is insufficient phosphorus, i.e. there is excess nitrogen. If an area is phosphorus limited, then adding phosphorus will increase phytoplankton growth. Phosphorus limitation occurs in some locations in the spring when large amounts of nitrogen are added to the estuary from stormwater flow.

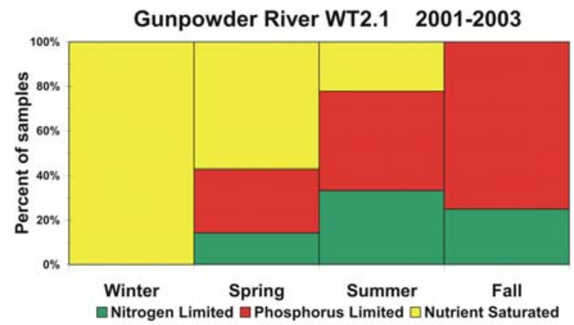
If an area is light limited, then both nitrogen and phosphorus are available in excess and a situation of nutrient saturation occurs. In this case, if phytoplankton are exposed to appropriate water temperatures and sufficient light, they will grow. If an area is both nitrogen and phosphorus limited, then both nitrogen and phosphorus must be added to increase algal growth.

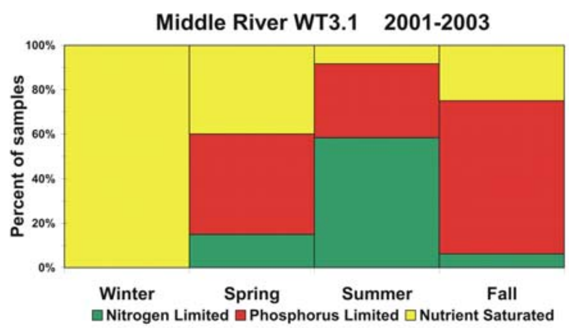
Managers can use the nutrient limitation model to predict which nutrient is limiting at a given location and use the information to assess what management approach might be the most effective for controlling excess phytoplankton growth. If an area is phosphorus limited, then reducing phosphorus will bring the most immediate reductions in phytoplankton grown. However, if nitrogen levels are not also reduced, the excess nitrogen that goes unused can be exported downstream. This excess nitrogen may reach an area that is nitrogen limited, fueling phytoplankton growth in that downstream area.

The nutrient limitation predictions are a valuable tool, but they must be used in conjunction with other water quality and watershed information to fully assess and evaluate the best management approach.

The resource limitation models were used to predict resource limitation for the three stations in the Upper Western Shore Basin. Results are summarized graphically for the most recent three-year period (2001-2003) by season: winter (December-February), spring (March-May), summer (July-September) and fall (October-November). For a text description of the information presented here graphically, see Appendix C.

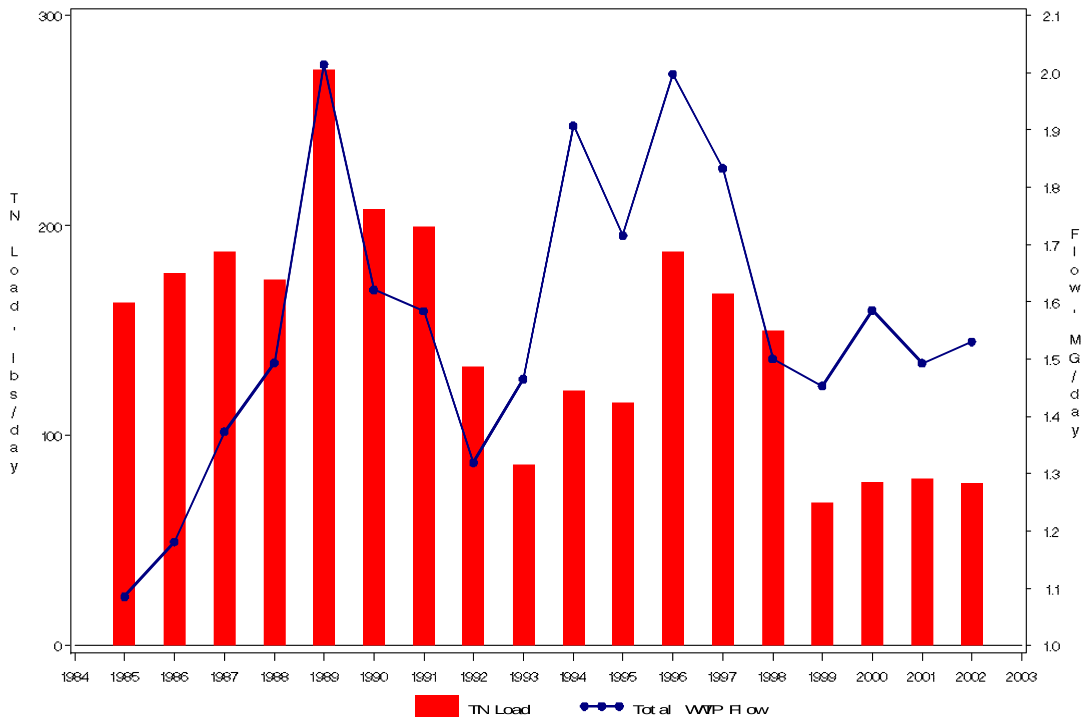

Bush River WT1.1 2001-2003
100%
80%
60%
40%
20%
0%
Percent of samples
Winter
Spring
Summer
Fall
Nitrogen Limited
Phosphorus Limited
Nutrient Saturated


Gunpowder River WT2.1 2001-2003
100%
80%
60%
40%
20%
0%
Percent of samples
Winter
Spring
Summer
Fall
Nitrogen Limited
Phosphorus Limited
Nutrient Saturated

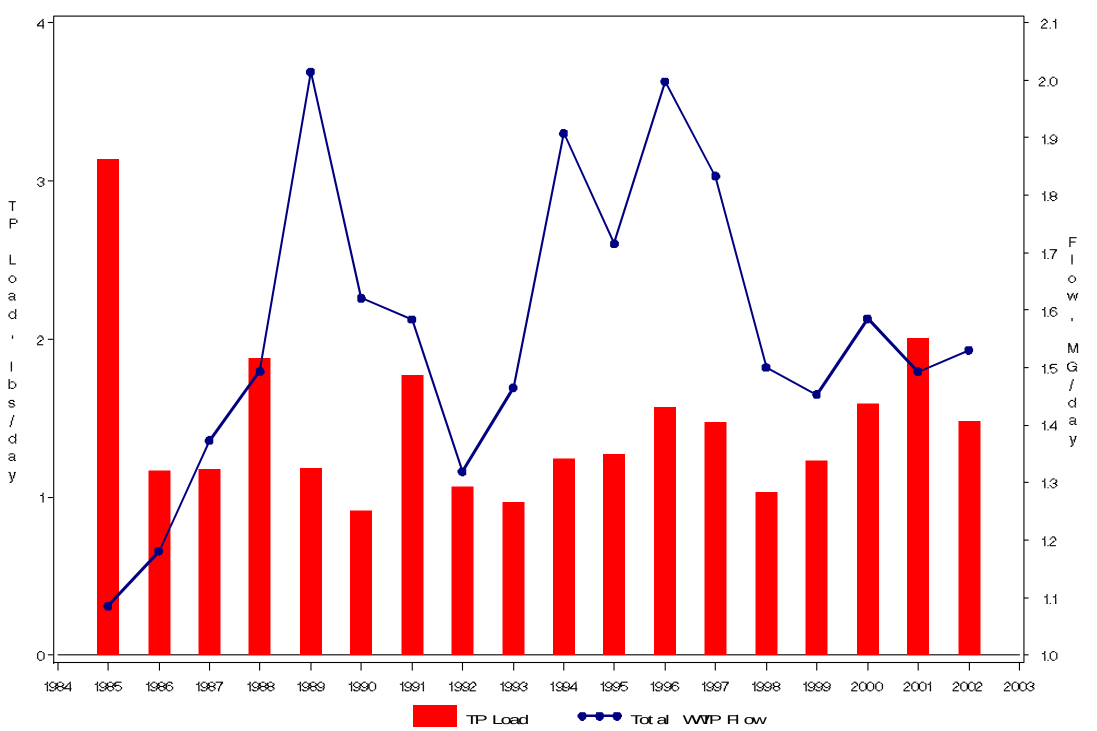

Middle River WT3.1 2001-2003
100%
80%
60%
40%
20%
0%
Percent of samples
Winter
Spring
Summer
Fall
Nitrogen Limited
Phosphorus Limited
Nutrient Saturated

Appendix A – Nutrient Loads from Major WWTPs in the Upper Western Shore

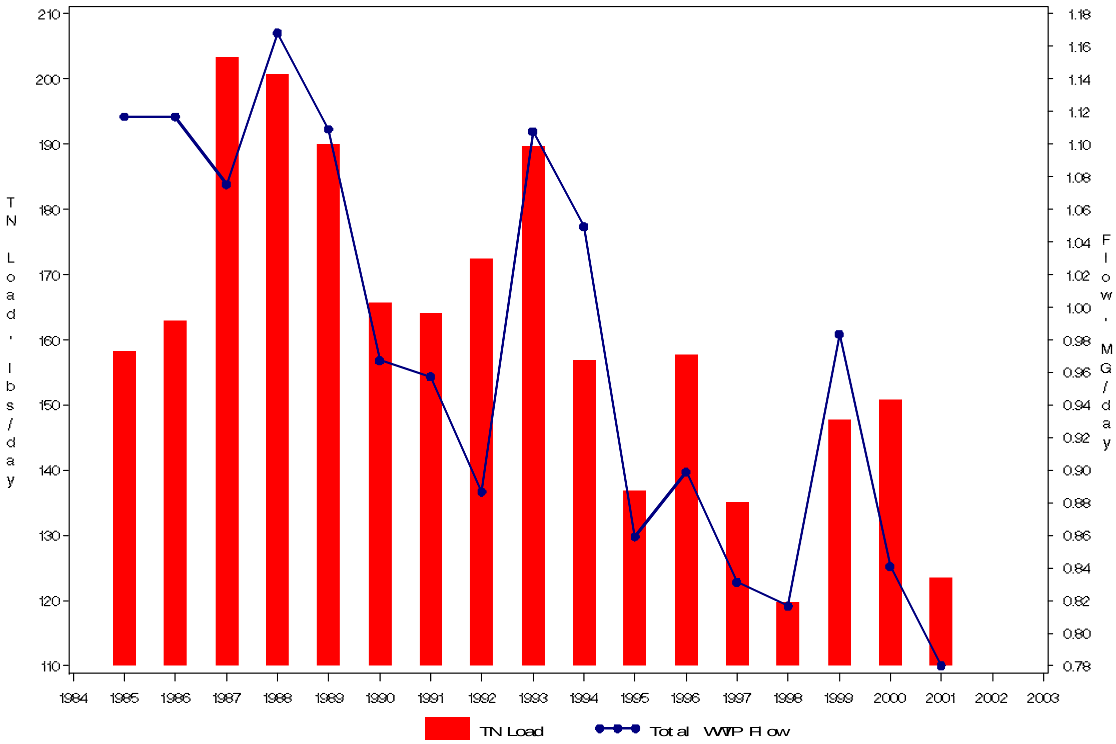
ABERDEEN Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



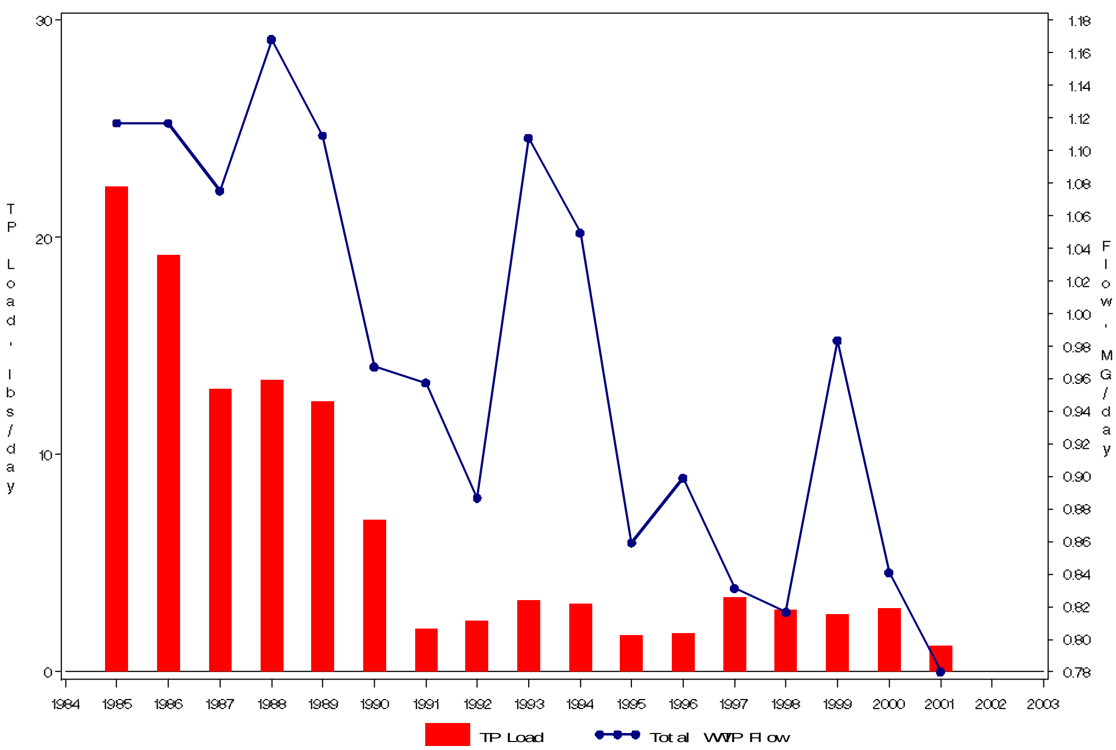
ABERDEEN Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow



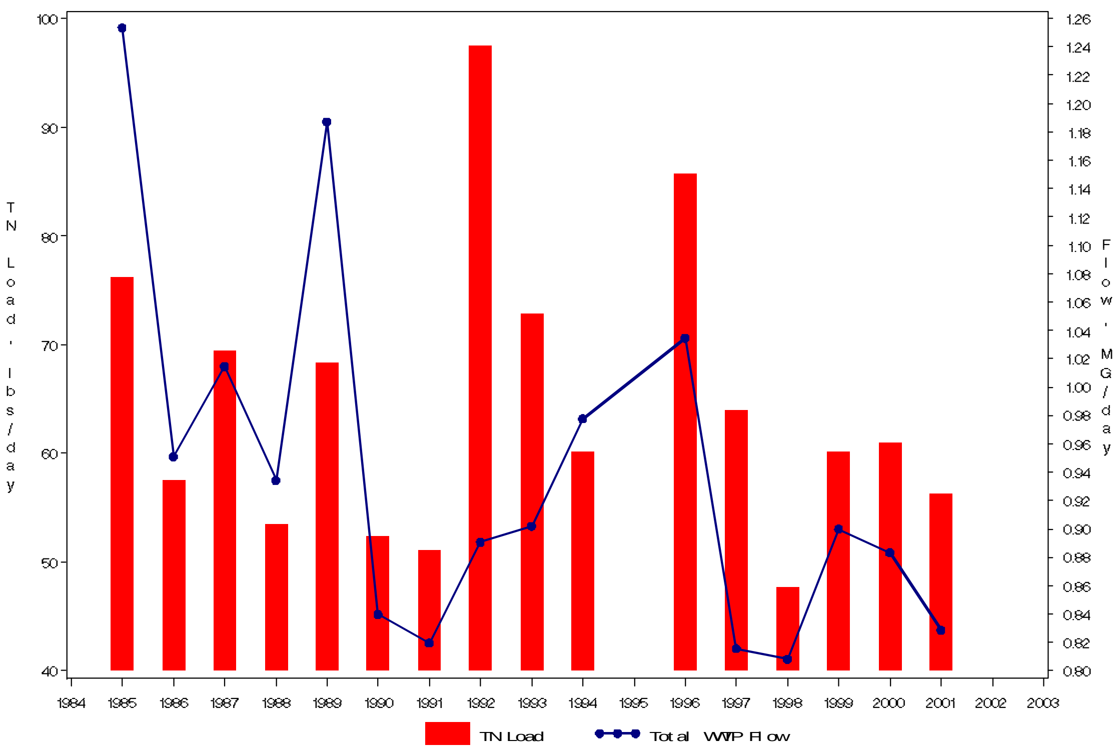
APG—ABERDEEN Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



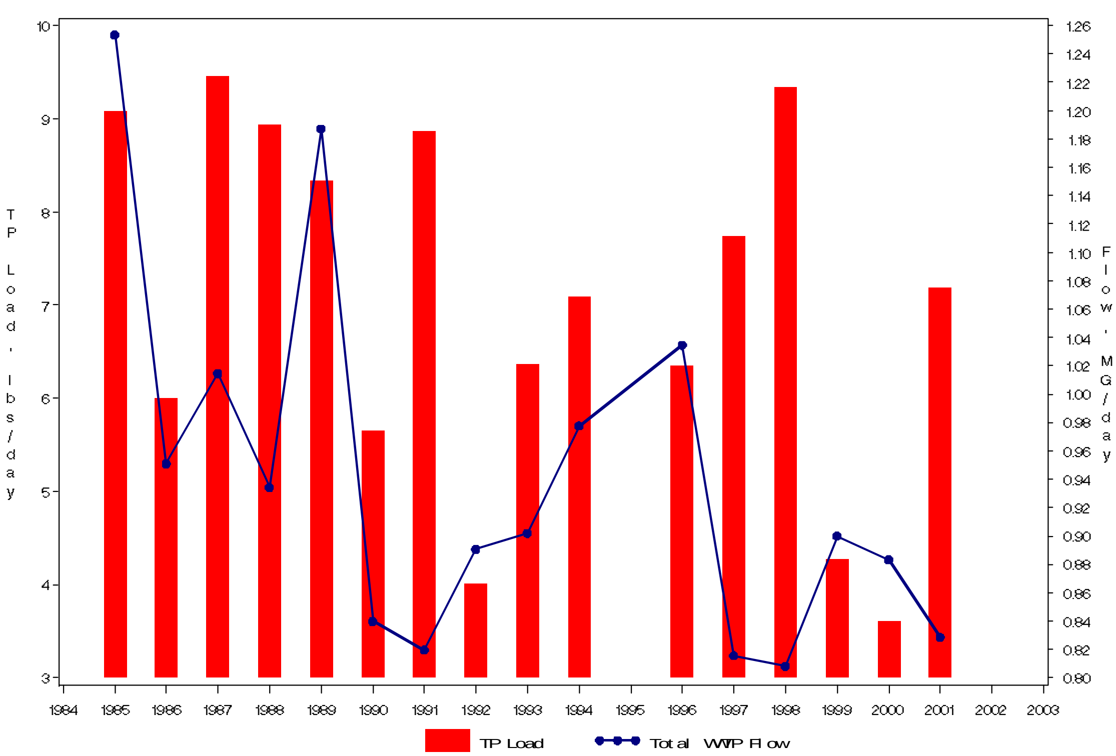
APG—ABERDEEN Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow



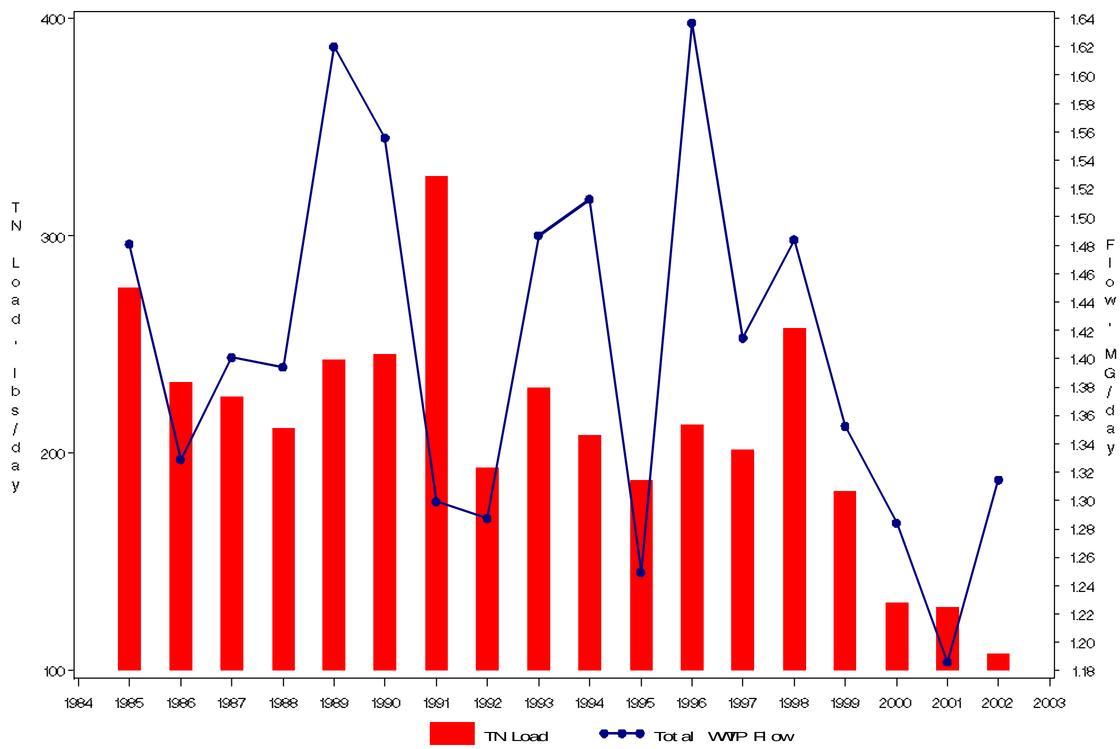
APG–EDGEWOOD Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



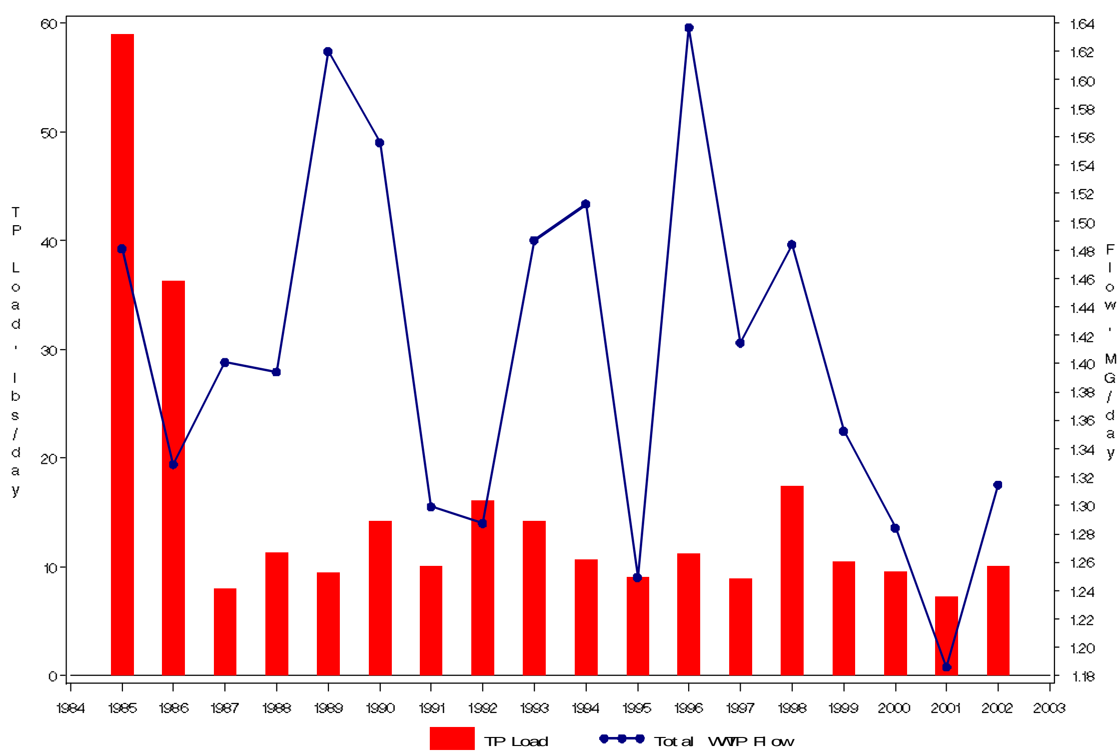
APG–EDGEWOOD Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow



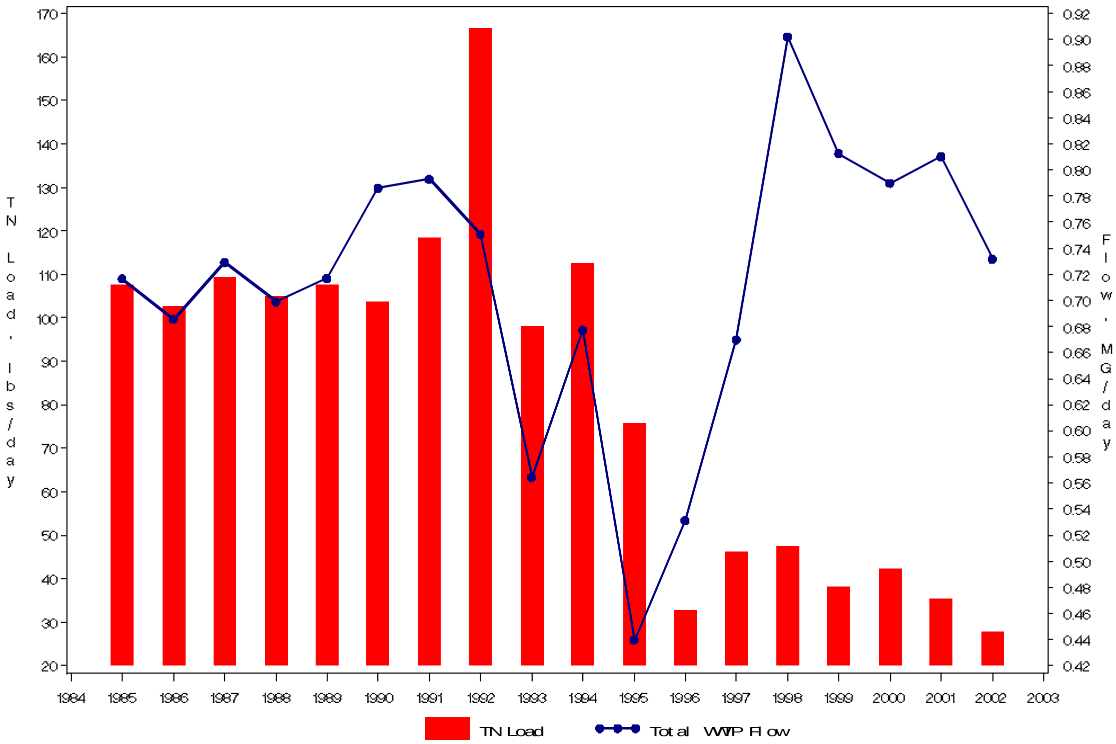
HAVRE DE GRACE Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



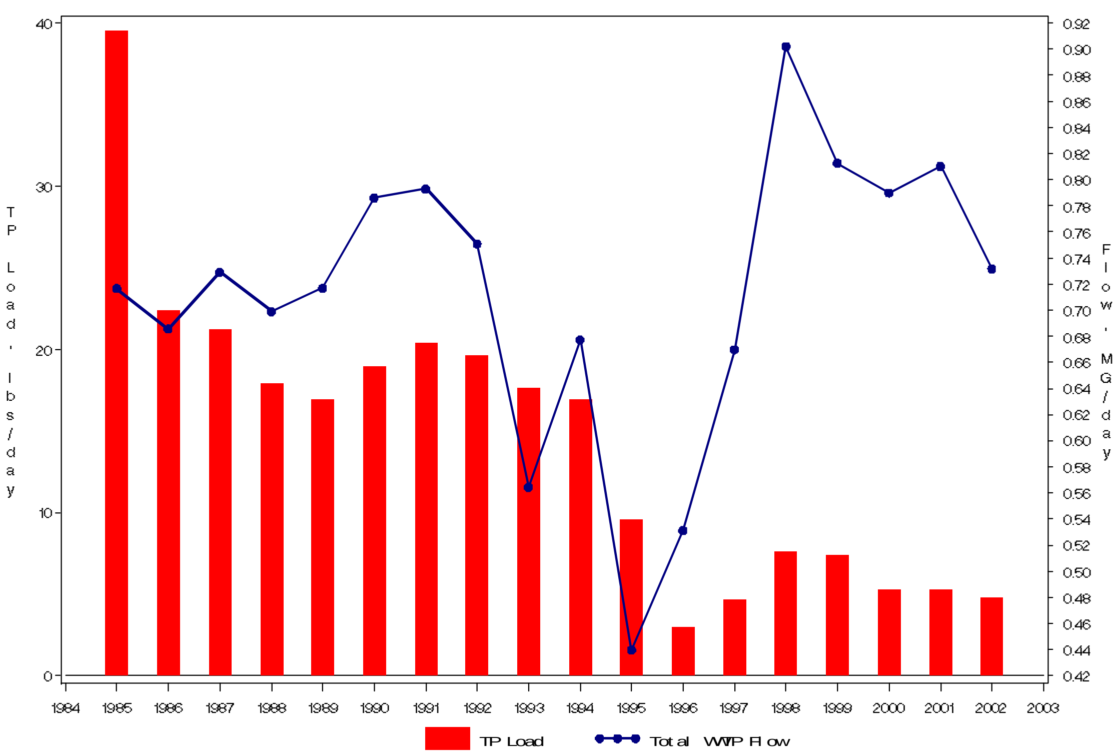
HAVRE DE GRACE Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow



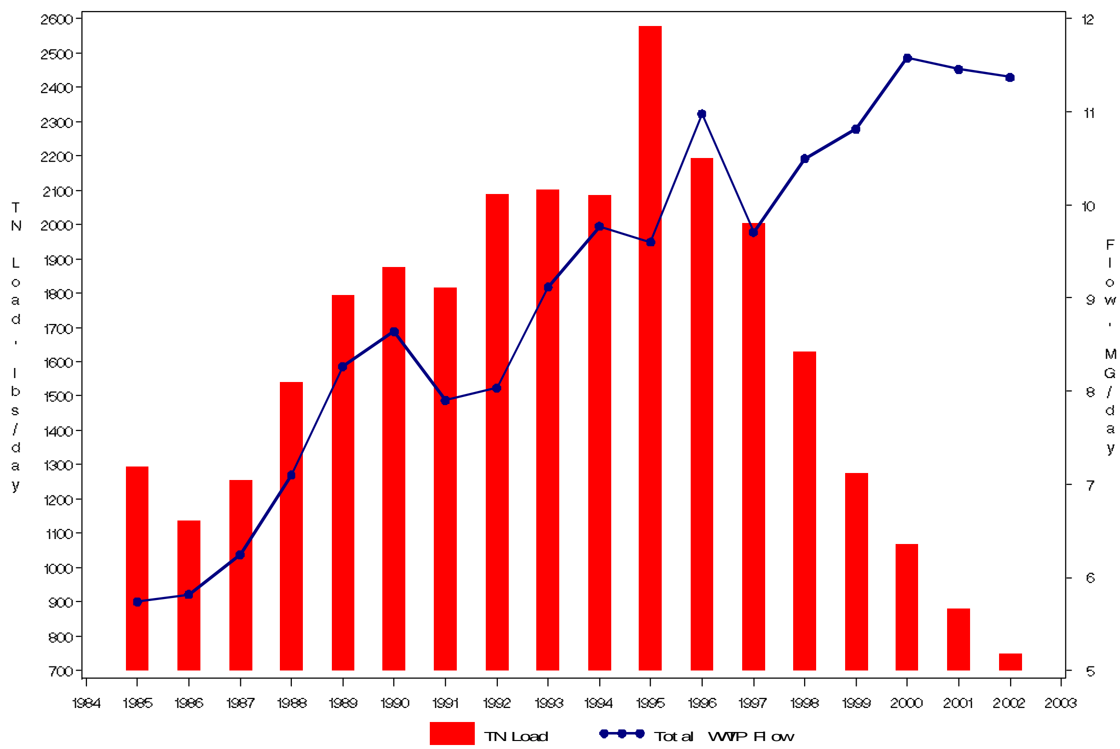
JOPPATOWNE Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



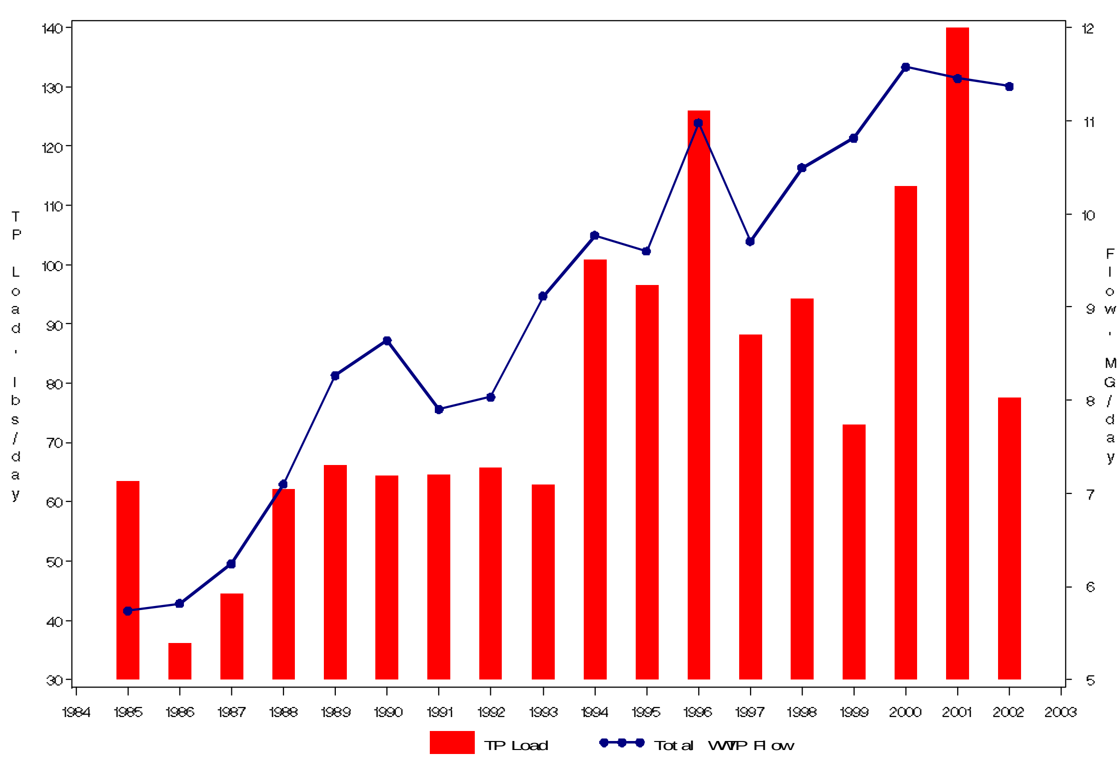
JOPPATOWNE Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow



SOD RUN Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



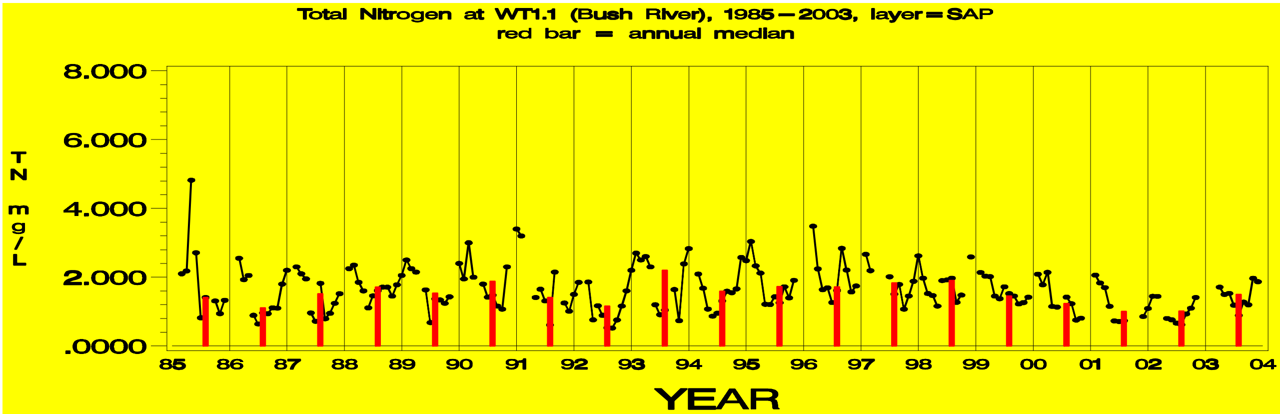
SOD RUN Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow

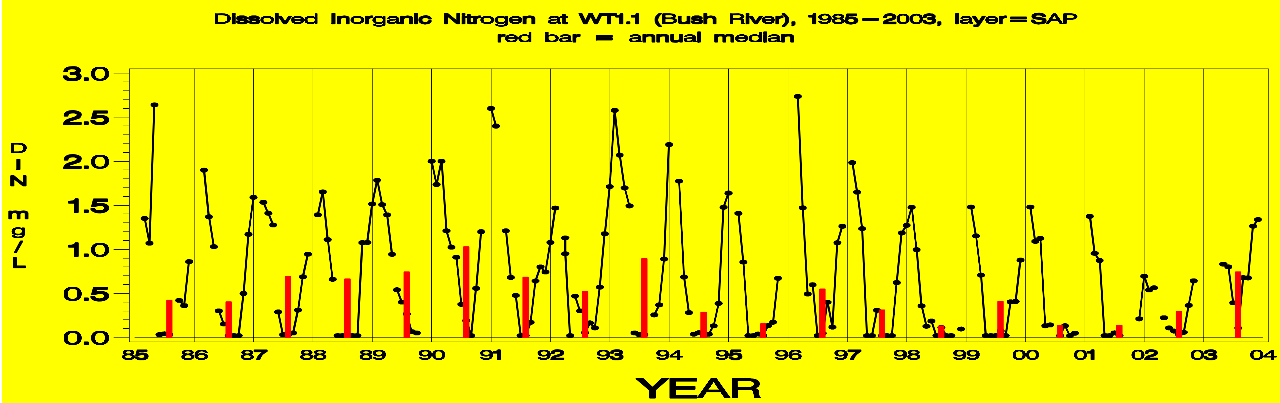


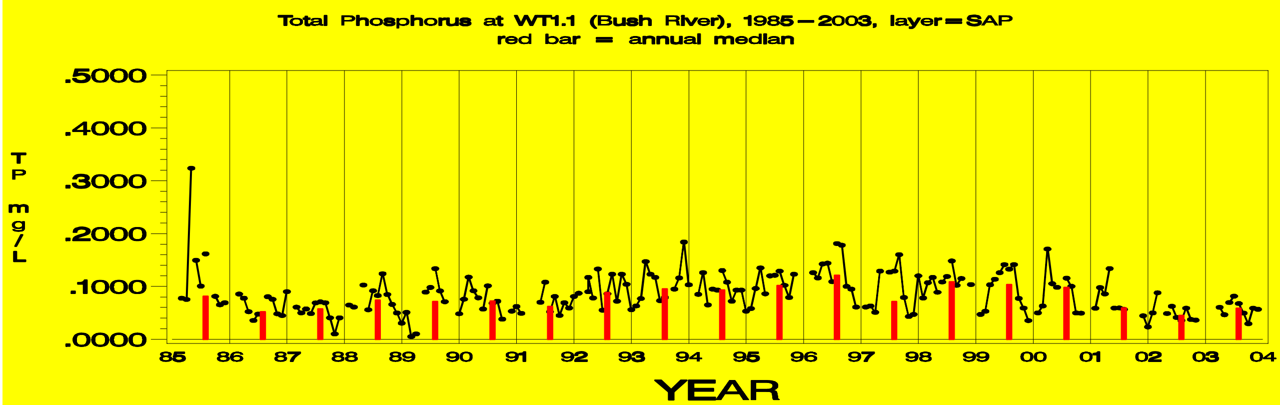
Appendix B – Measured Water Quality Concentrations for the Upper Western Shore Basin

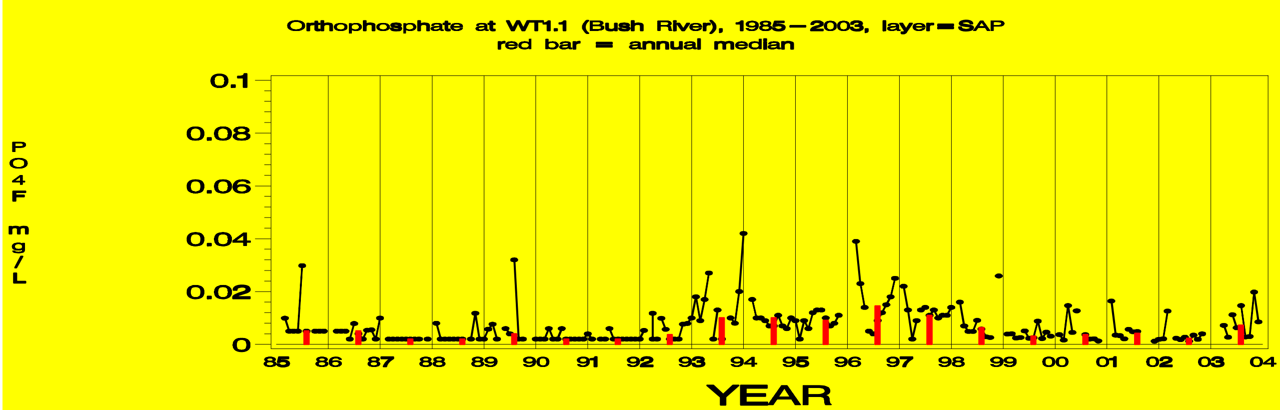
Water quality concentrations based on measured concentration data taken at long-term stations are graphed as follows. Mean concentration for the surface and above pycnocline data are shown for each sampling date as black dots. Annual median of those values is shown as red bar.

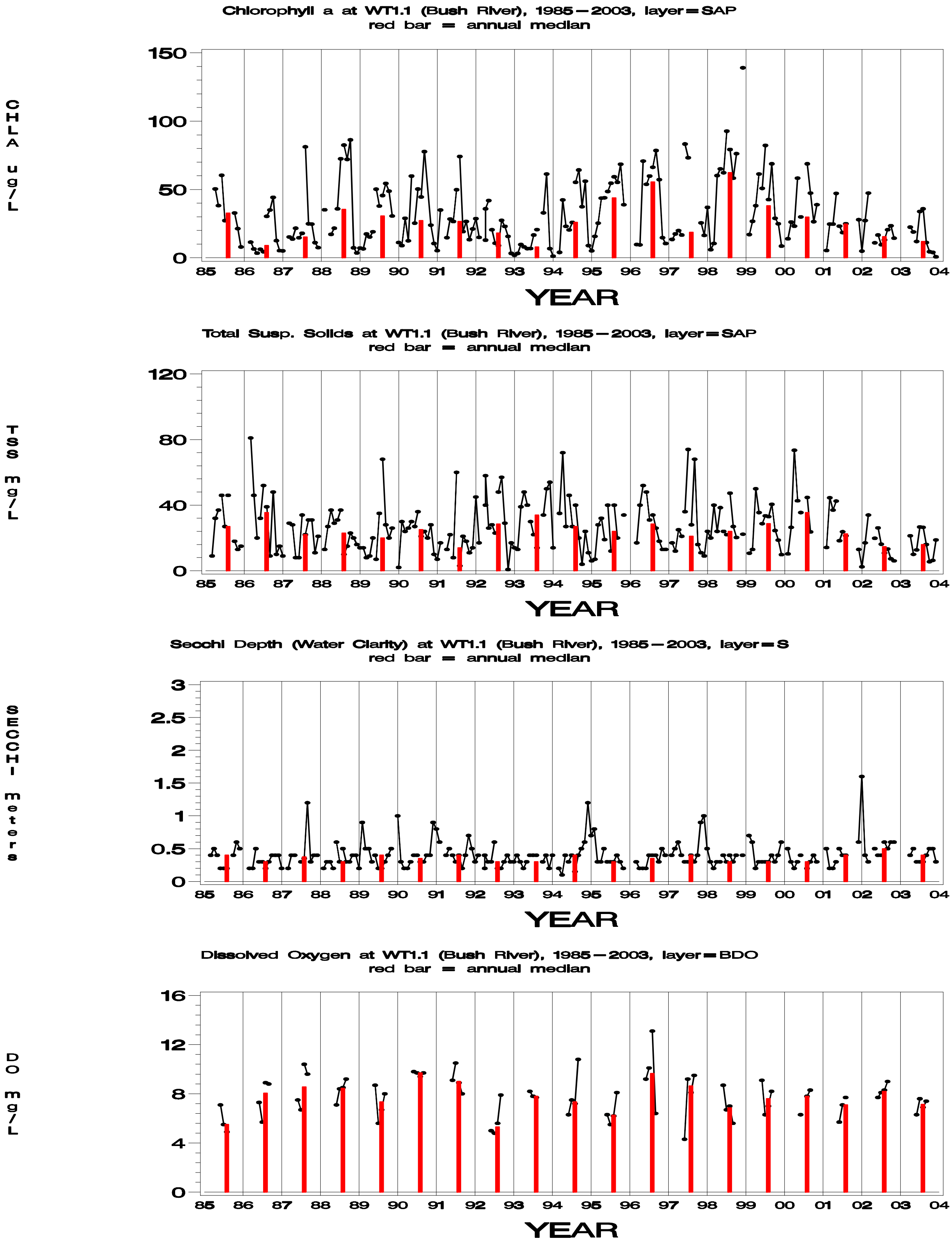
Note that parameter values tend to fluctuate highly from year to year, and much of this fluctuation can be attributed to flow conditions. For example, in high flow years (wet years), nutrient levels are higher than in dry years. Also, the timing of the spring freshet and other weather conditions can determine the strength and duration of the pycnocline, strongly affecting dissolved oxygen levels. Topography, hydrogeology, stream hydrology, how a basin is developed and management actions all affect the influence of weather conditions.


Total Nitrogen at WT1.1 (Bush River), 1985-2003, layer=SAP
red bar = annual median
T N mg/L
8.000
6.000
4.000
2.000
.0000
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04
YEAR

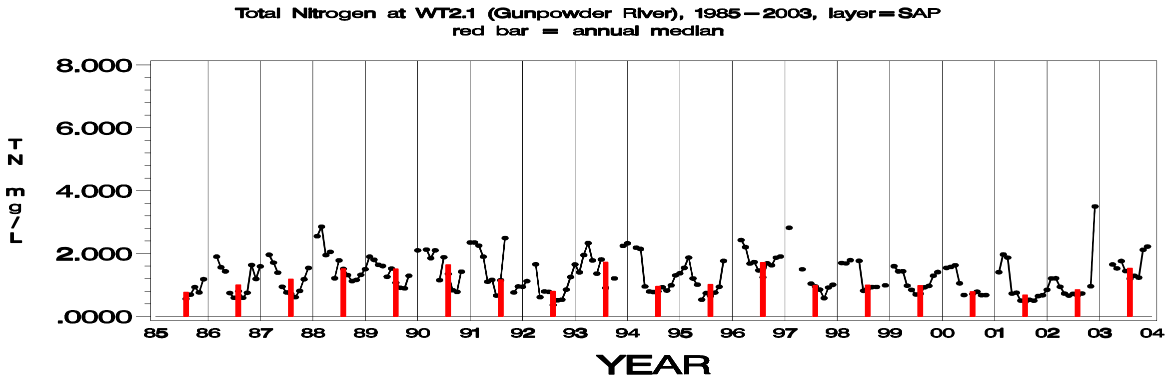

Dissolved Inorganic Nitrogen at WT1.1 (Bush River), 1985-2003, layer=SAP
red bar = annual median
DIN mg/L
3.0
2.5
2.0
1.5
1.0
0.5
0.0
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04
YEAR

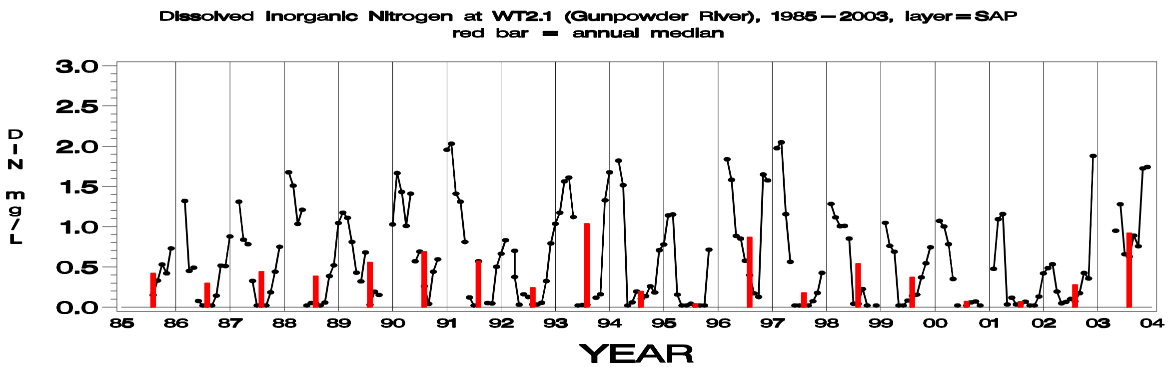

Total Phosphorus at WT1.1 (Bush River), 1985-2003, layer=SAP
red bar = annual median
TP mg/L
.5000
.4000
.3000
.2000
.1000
.0000
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04
YEAR

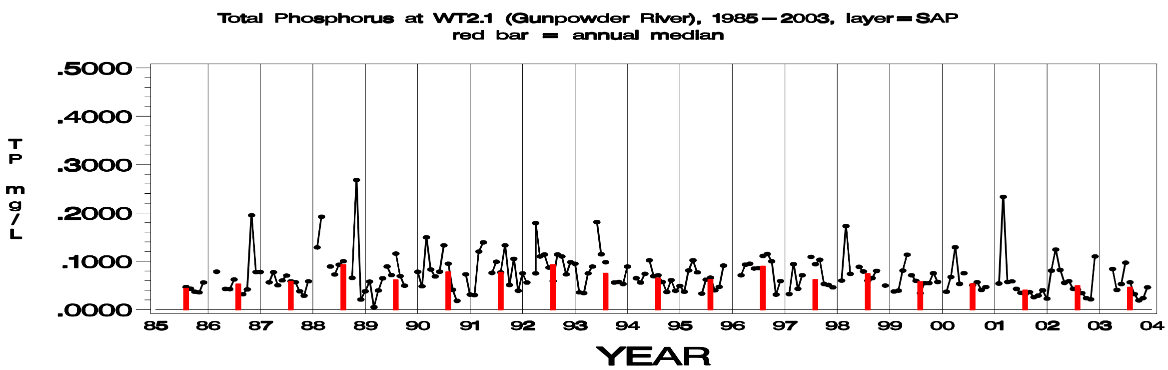

Orthophosphate at WT1.1 (Bush River), 1985-2003, layer=SAP
red bar = annual median
PO4F mg/L
0.1
0.08
0.06
0.04
0.02
0
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04
YEAR

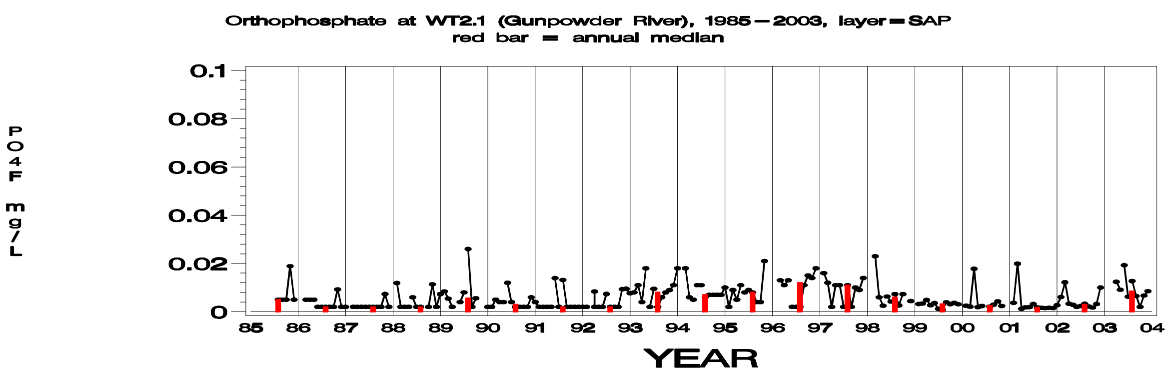


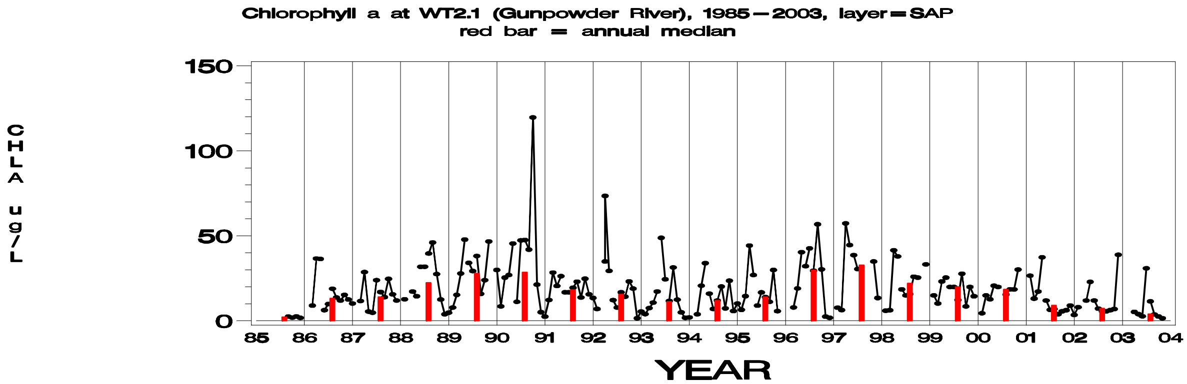
Chlorophyll a at WT1.1 (Bush River), 1985-2003, layer=SAP
red bar = annual median
CHLA ug/L
YEAR
Total Susp. Solids at WT1.1 (Bush River), 1985-2003, layer=SAP
red bar = annual median
TSS mg/L
YEAR
Secchi Depth (Water Clarity) at WT1.1 (Bush River), 1985-2003, layer=S
red bar = annual median
SECCHI meters
YEAR
Dissolved Oxygen at WT1.1 (Bush River), 1985-2003, layer=BDO
red bar = annual median
DO mg/L
YEAR

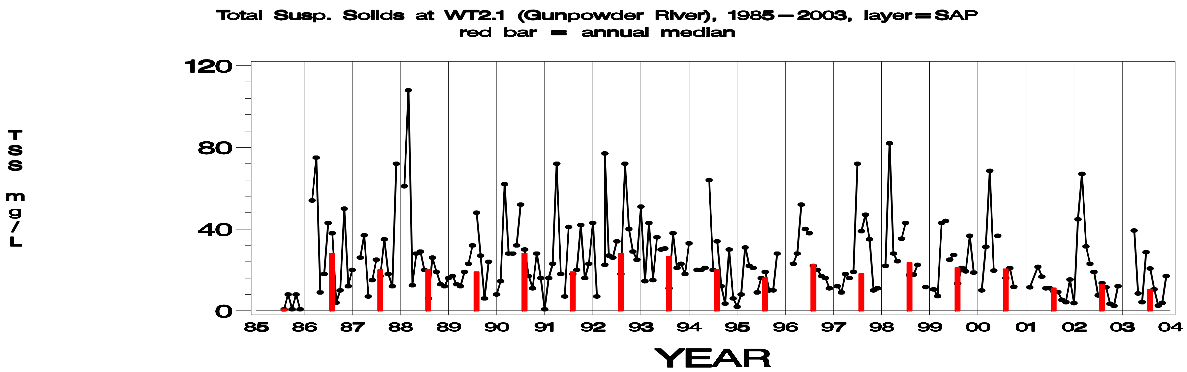

Total Nitrogen at WT2.1 (Gunpowder River), 1985-2003, layer=SAP
red bar = annual median
TN mg/L
YEAR

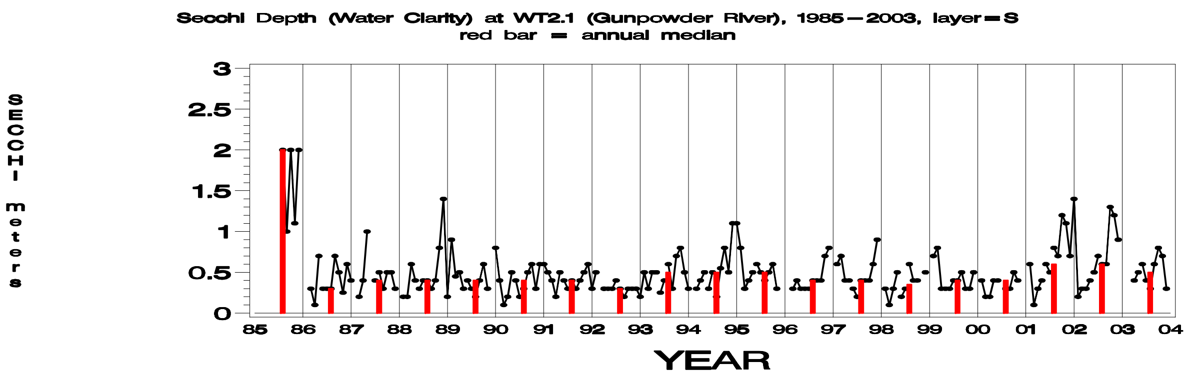

Dissolved Inorganic Nitrogen at WT2.1 (Gunpowder River), 1985-2003, layer=SAP
red bar = annual median
DIN mg/L
YEAR

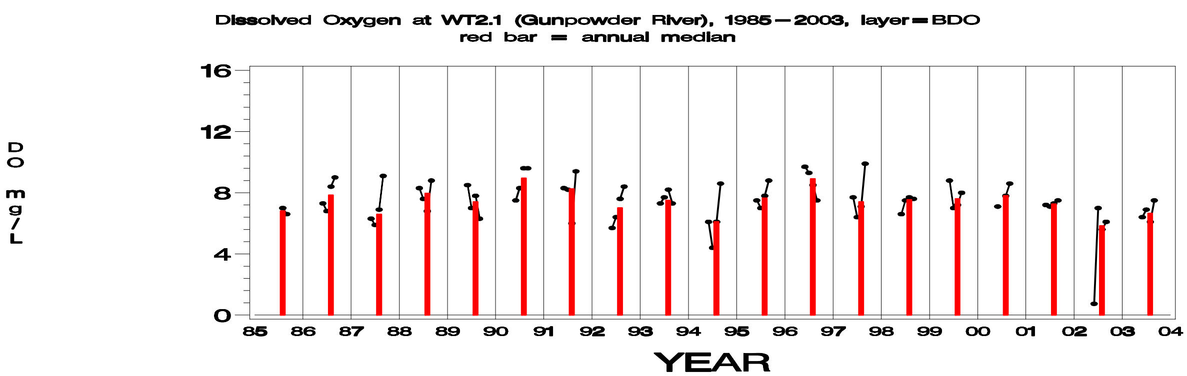

Total Phosphorus at WT2.1 (Gunpowder River), 1985-2003, layer=SAP
red bar = annual median
TP mg/L
YEAR

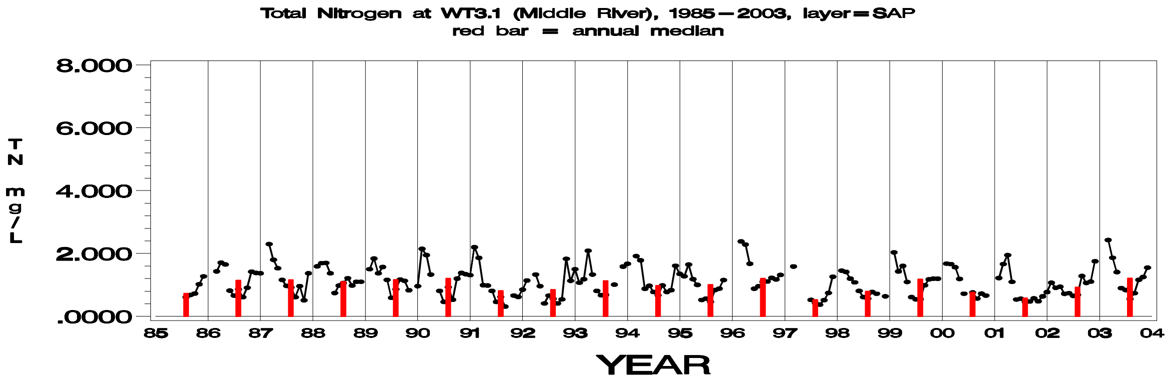

Orthophosphate at WT2.1 (Gunpowder River), 1985-2003, layer=SAP
red bar = annual median
PO4F mg/L
YEAR

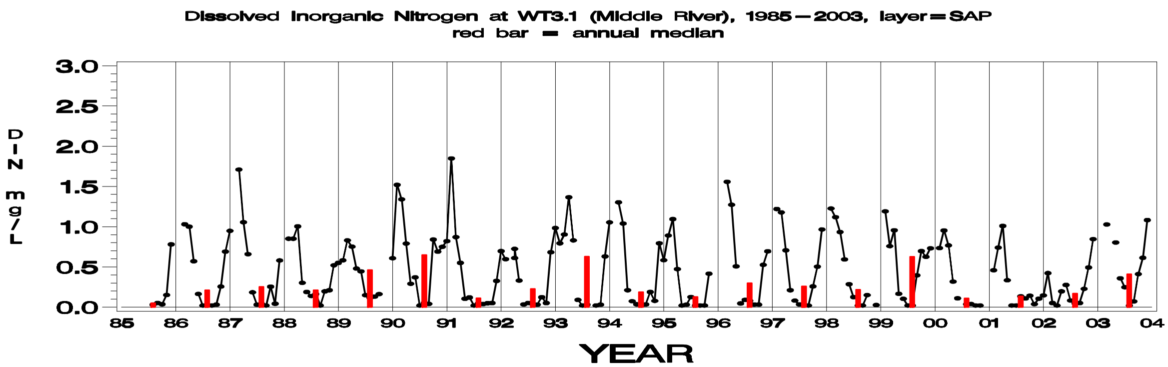

Chlorophyll a at WT2.1 (Gunpowder River), 1985-2003, layer=SAP
red bar = annual median
CHLA ug/L
150
100
50
0
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04
YEAR

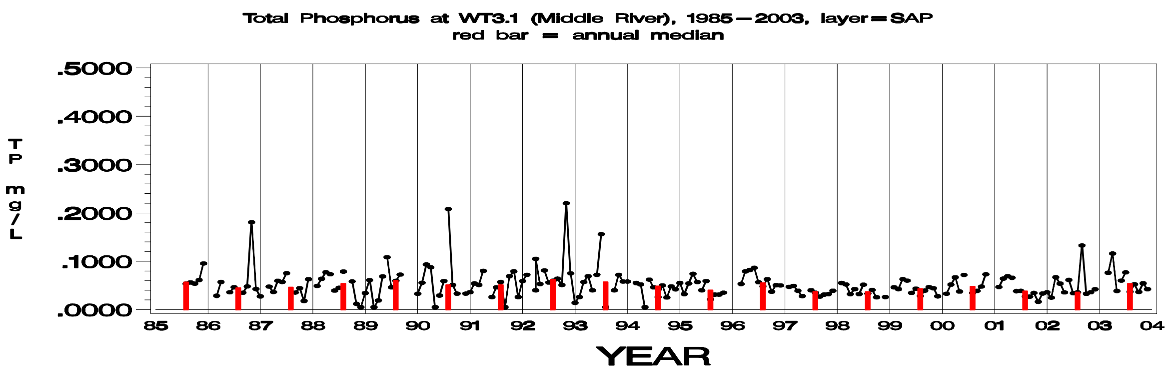

Total Susp. Solids at WT2.1 (Gunpowder River), 1985-2003, layer=SAP
red bar = annual median
TSS mg/L
120
80
40
0
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04
YEAR

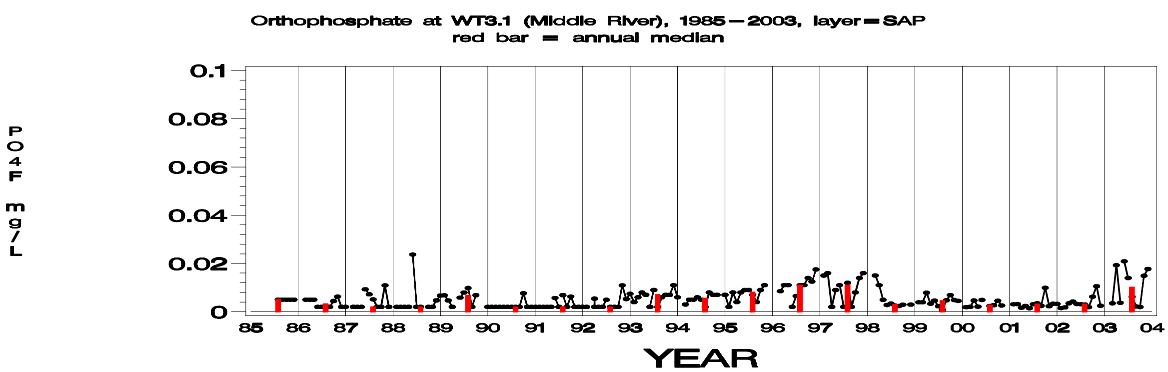

Secchi Depth (Water Clarity) at WT2.1 (Gunpowder River), 1985-2003, layer=S
red bar = annual median
SECCHI meters
3
2.5
2
1.5
1
0.5
0
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04
YEAR


Dissolved Oxygen at WT2.1 (Gunpowder River), 1985-2003, layer=BDO
red bar = annual median
DO mg/L
16
12
8
4
0
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04
YEAR

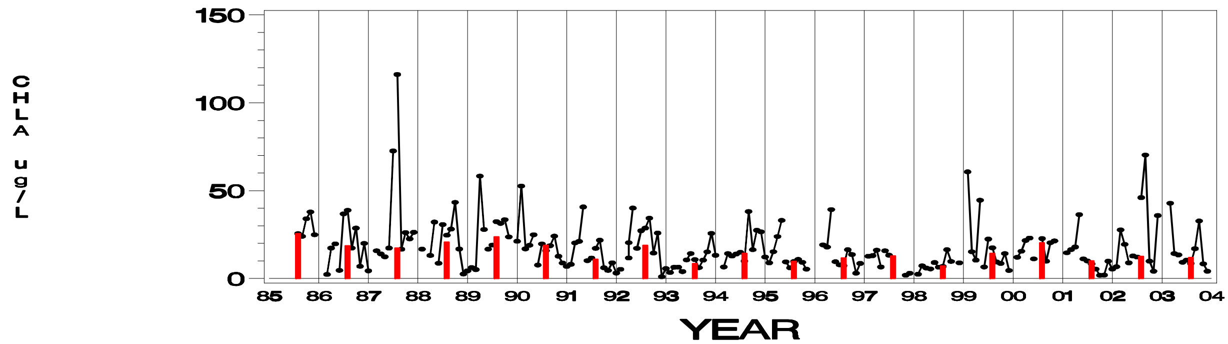

Total Nitrogen at WT3.1 (Middle River), 1985-2003, layer=SAP
red bar = annual median
TN mg/L
8.000
6.000
4.000
2.000
.0000
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04
YEAR


Dissolved Inorganic Nitrogen at WT3.1 (Middle River), 1985-2003, layer=SAP
red bar = annual median
DIN mg/L
3.0
2.5
2.0
1.5
1.0
0.5
0.0
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04
YEAR

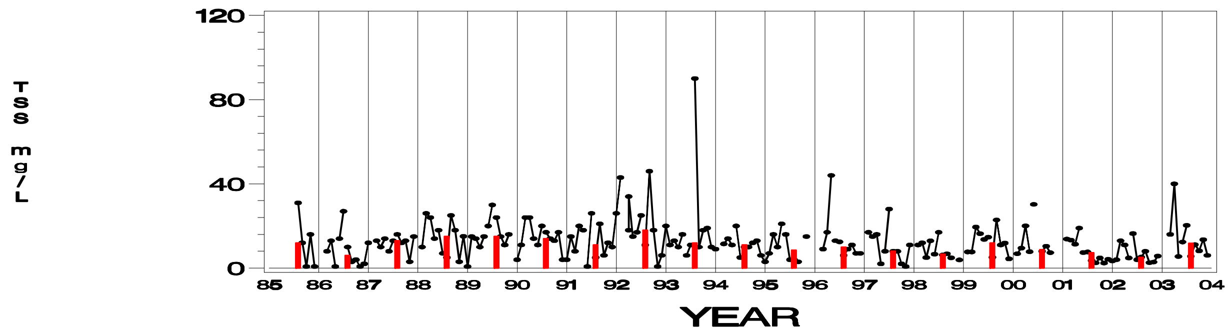

Total Phosphorus at WT3.1 (Middle River), 1985-2003, layer=SAP
red bar = annual median
TP mg/L
.5000
.4000
.3000
.2000
.1000
.0000
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04
YEAR


Orthophosphate at WT3.1 (Middle River), 1985-2003, layer=SAP
red bar = annual median
PO4F mg/L
0.1
0.08
0.06
0.04
0.02
0
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04
YEAR

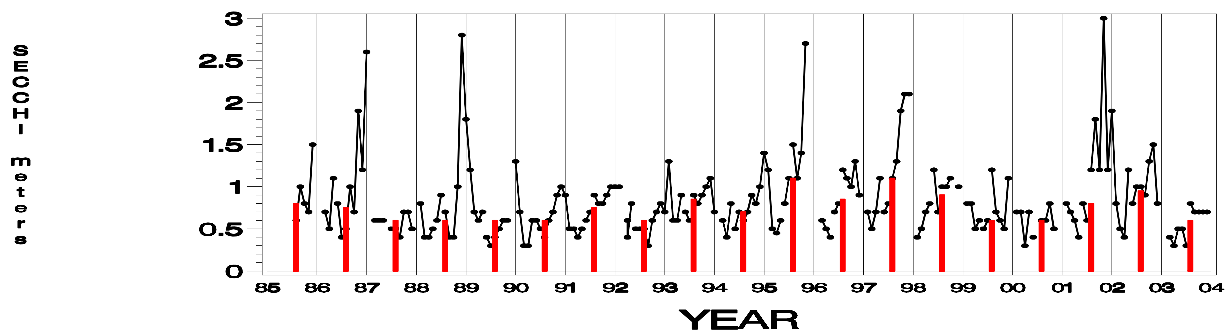
Chlorophyll a at WT3.1 (Middle River), 1985—2003, layer=SAP
red bar = annual median



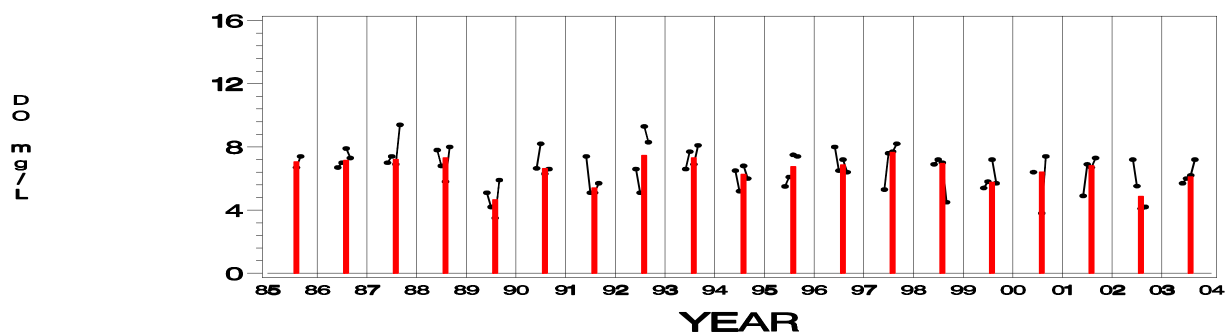
Total Susp. Solids at WT3.1 (Middle River), 1985—2003, layer=SAP
red bar = annual median



Secchi Depth (Water Clarity) at WT3.1 (Middle River), 1985—2003, layer=S
red bar = annual median



Dissolved Oxygen at WT3.1 (Middle River), 1985—2003, layer=BDO
red bar = annual median



Appendix C – Nutrient Limitation Graphs for the Upper Western Shore River Basin

The resource limitation models were used to predict resource limitation for the three stations in the Upper Western Shore Basin. Results are summarized for the most recent three-year period (2001-2003) by season: winter (December-February), spring (March-May), summer (July-September) and fall (October-November). Managers can use these predictions to assess what management approach will be the most effective for controlling excess phytoplankton growth. Interpreting the results can be a little counter-intuitive, however. Remember that nitrogen limited means that *phosphorus* is in excess. Initially, it would seem that the best management strategy would be to reduce phosphorus inputs. However, it may actually be more cost effective to further reduce *nitrogen* inputs to increase the amount of 'unbalance' in the relative proportions of nutrients so that phytoplankton growth is even more limited. When used along with other information available from the water quality and watershed management programs, these predictions will allow managers to make more cost-effective management decisions.

Bush River (WT1.1) - On an annual basis, phytoplankton growth is nitrogen limited 20 percent of the time and phosphorus limited 25 percent of the time. Winter growth is entirely nutrient saturated (light limited or no limitation). Spring growth is nitrogen limited and phosphorus limited more than 15 percent of the time each, and nutrient saturated the remainder of the time. Summer growth is nitrogen limited about 45 percent of the time and phosphorus limited almost 20 percent of the time. Fall growth is phosphorus limited 75 percent of the time and otherwise nutrient saturated. Relative status of total nitrogen, total phosphorus and dissolved inorganic phosphorus concentrations are all good; dissolved inorganic nitrogen concentration is relatively fair and is improving (decreasing). Dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is decreasing; still, this ratio is high in winter, spring and fall, indicating that decreases in phosphorus will help limit phytoplankton growth. Further reductions in nitrogen concentration will enhance nitrogen limitation throughout the year.

Gunpowder River (WT2.1) - On an annual basis, phytoplankton growth is nitrogen limited more than 20 percent of the time and phosphorus limited 40 percent of the time. Winter growth is entirely nutrient saturated (light limited or no limitation). Spring growth is phosphorus limited almost 30 percent of the time and nitrogen limited almost 15 percent of the time. Summer growth is nitrogen limited about 35 percent of the time and phosphorus limited almost 45 percent of the time. Fall growth is nitrogen limited 25 percent of the time and phosphorus limited 75 percent of the time. Relative status of total nitrogen, total phosphorus and dissolved inorganic phosphorus concentrations are all good; dissolved inorganic nitrogen concentration is relatively fair. Total nitrogen concentration is improving (decreasing). Dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is decreasing; this ratio is high in fall. Reductions in both nitrogen and phosphorus have the potential to limit algal growth locally in the Gunpowder River.

Middle River (WT3.1) – On an annual basis, phytoplankton growth is nitrogen limited almost 25 percent of the time and phosphorus limited more than 35 percent of the time.

Growth in the winter is nutrient saturated (light limited or no limitation). Growth in the spring is phosphorus limited 45 percent of the time and nitrogen limited 15 percent of the time. Growth in the summer is nitrogen limited almost 60 percent of the time and phosphorus limited almost 35 percent of the time. Growth in the fall is phosphorus limited almost 70 percent of the time and nitrogen limited more than 50 percent of the time. Total nitrogen, dissolved inorganic nitrogen, total phosphorus and dissolved inorganic phosphorus concentrations are all relatively good and total nitrogen and total phosphorus concentrations are improving (decreasing). The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is high in winter and spring, indicating that continued reductions in phosphorus, especially in the spring, have the potential to better limit phytoplankton growth locally in the Middle River. Continued reductions in nitrogen in summer and fall will also likely help further limit phytoplankton growth in these seasons.

Appendix D – Glossary

algae bloom – high concentrations of phytoplankton (algae).

benthos – bottom-dwellers.

dinoflagellates – a type of flagellated single-celled phytoplankton; most are photosynthesizers but some are also heterotrophic.

epiphytic – growing on a plant. Epiphytic algae grow on the leaves and stems of bay grasses.

estuary – a semi-enclosed, tidal, coastal body where fresh water running off land mixes with salt water coming in from the ocean.

hypoxia – the condition of low dissolved oxygen (< 2 mg/L), which is detrimental to many living organisms.

nauplius – an early planktonic stage in the life of a crustacean.

nutrient – chemicals required for plant growth and reproduction; in this report the term nutrients generally refers to nitrogen and phosphorus.

plankton - organisms that are unable to swim strongly, and drift along with currents; many are microscopic

phytoplankton – plankton that are "plant-like" in that they are primarily or partially autotrophic (primary producers); many are tiny single-celled organisms; examples include diatoms and dinoflagellates.

tributary – a stream, creek or river that feeds into a larger body of water.

watershed – a basin that drains into a particular body of water.

zooplankton – plankton that tend to be "animal-like" in that they are primarily heterotrophic (e.g., they eat other organisms); examples include copepods and rotifers.

Appendix E – References

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